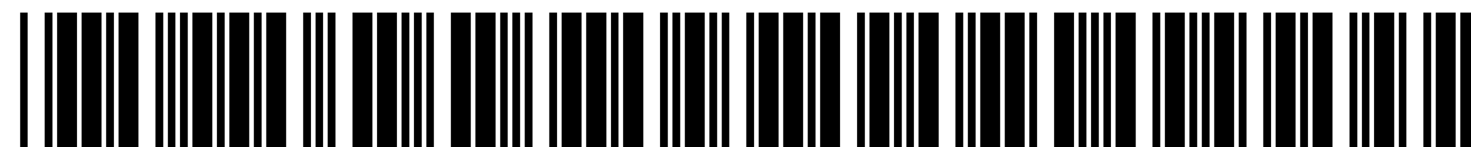
US007279259B2

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Ito et al.

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(45) **Date of Patent:** **Oct. 9, 2007**

(54) **METHOD FOR CORRECTING PATTERN DATA AND METHOD FOR MANUFACTURING SEMICONDUCTOR DEVICE USING SAME**

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(73) Assignee: **Fujitsu Limited**, Kawasaki (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 131 days.

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(22) Filed: **Apr. 11, 2005**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**
G03F 9/00 (2006.01)

(52) **U.S. Cl.** **430/30**; 430/5; 430/311; 716/19; 716/21

(58) **Field of Classification Search** 430/5, 430/30, 311; 716/19, 21
See application file for complete search history.

(56) **References Cited**

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Patent Abstracts of Japan, Publication No. 2003-195478, dated Jul. 9, 2003.
Patent Abstracts of Japan, Publication No. 2002-006477, dated Jan. 9, 2002.

Primary Examiner—Christopher G. Young
(74) *Attorney, Agent, or Firm*—Westerman, Hattori, Daniels & Adrian, LLP.

(57) **ABSTRACT**

A method for correcting pattern data is provided which is capable of making a proper correction to data of a pattern having a complicated layout. A correction is made to pattern data affected by a proximity effect when a pattern is formed on a photomask or wafer according to design data for a semiconductor device, by detecting, according to the design data, a space portion being placed on a photomask or wafer and having a specified size occurring between patterns facing each other in a first direction, by producing pattern data corresponding to an assist pattern that fills the space portion, by detecting an edge to be corrected in a position being opposite to an edge of the assist pattern extending in a second direction between the patterns facing each other, out of framing portions of the pattern being placed in parallel and near to the assist pattern, by making a correction being independent of a correction to be made to other edge of the framing portion to the detected edge to be corrected, and by removing the assist pattern.

16 Claims, 22 Drawing Sheets

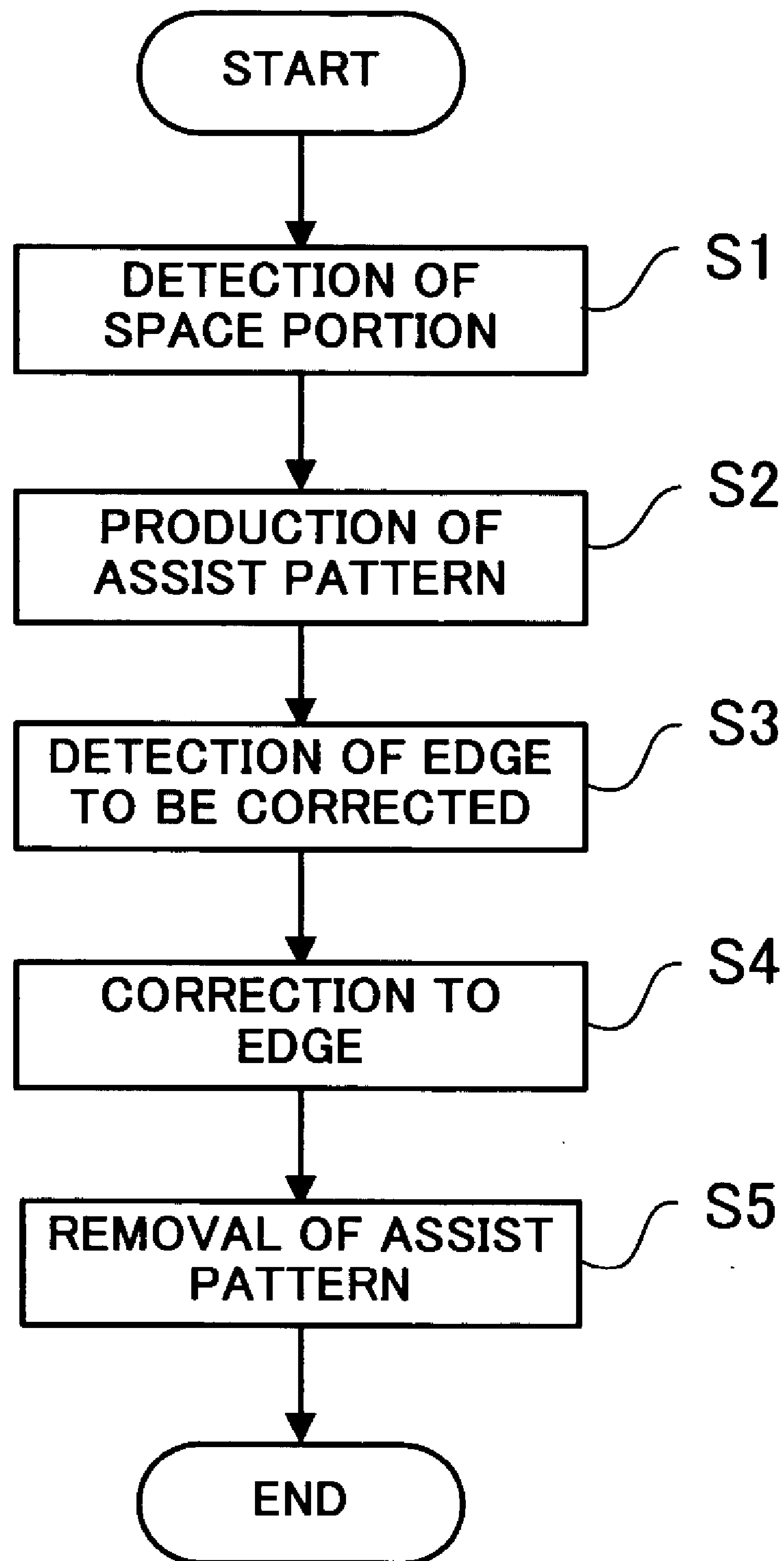

FIG. 1

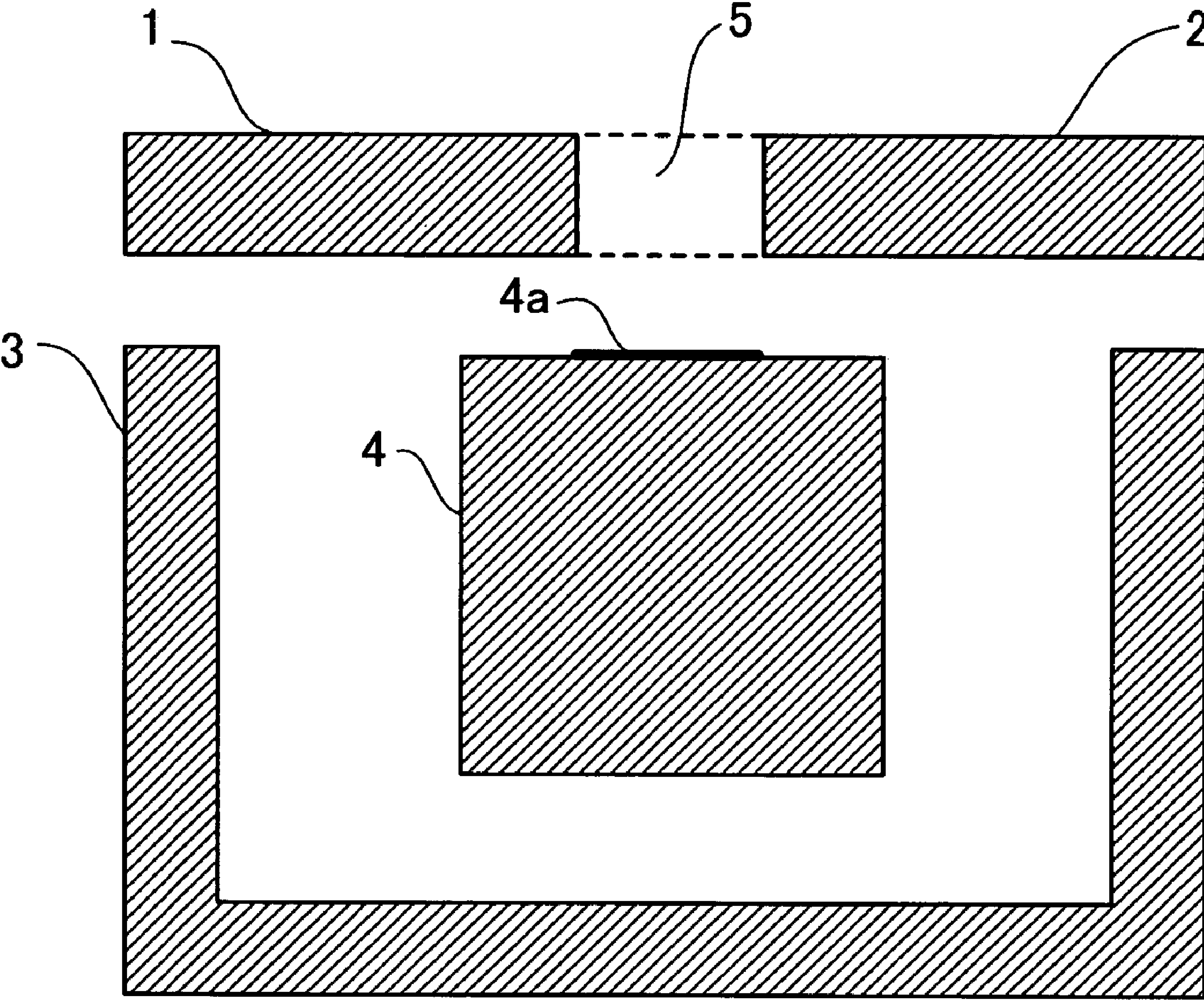

FIG. 2

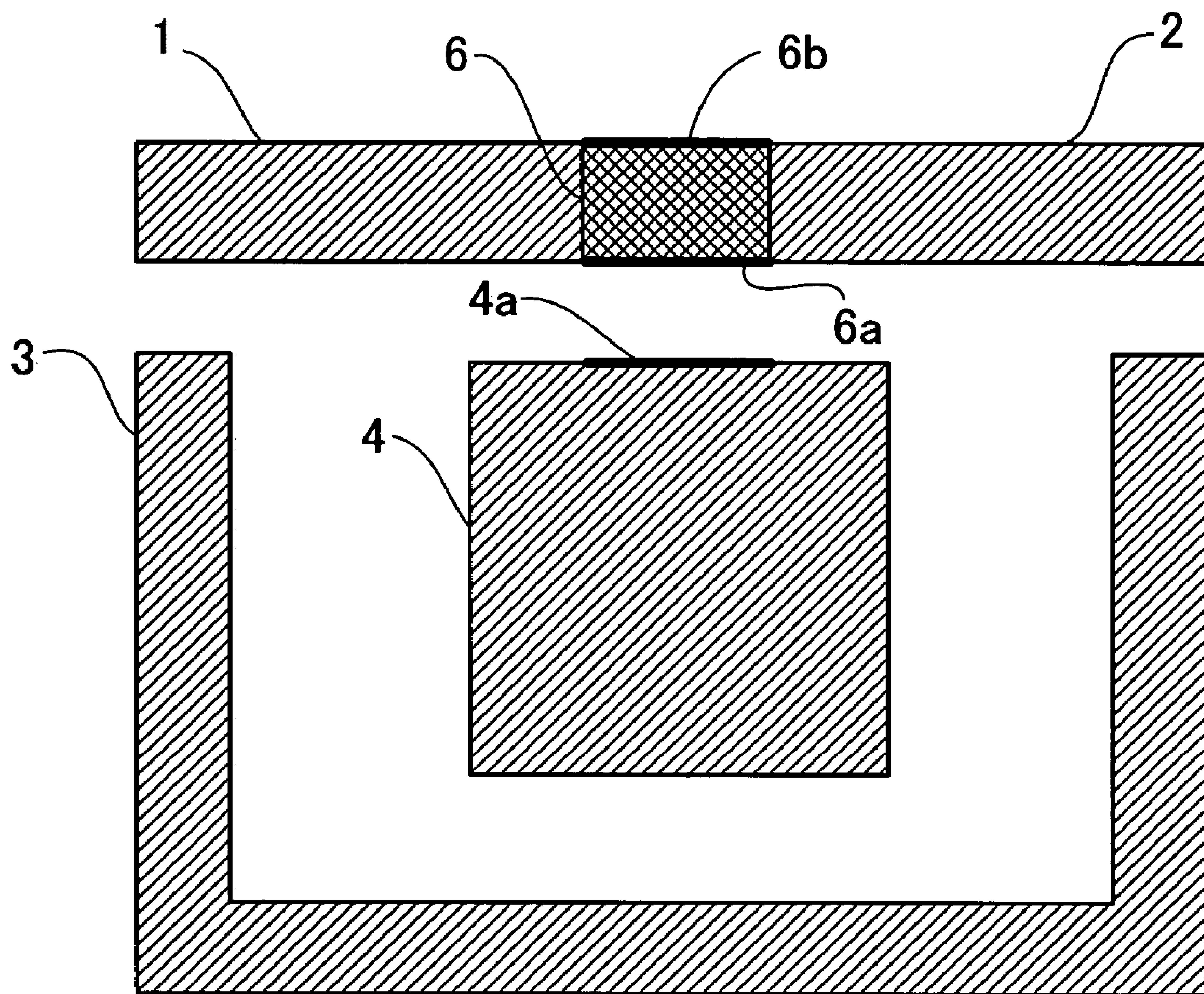

FIG. 3

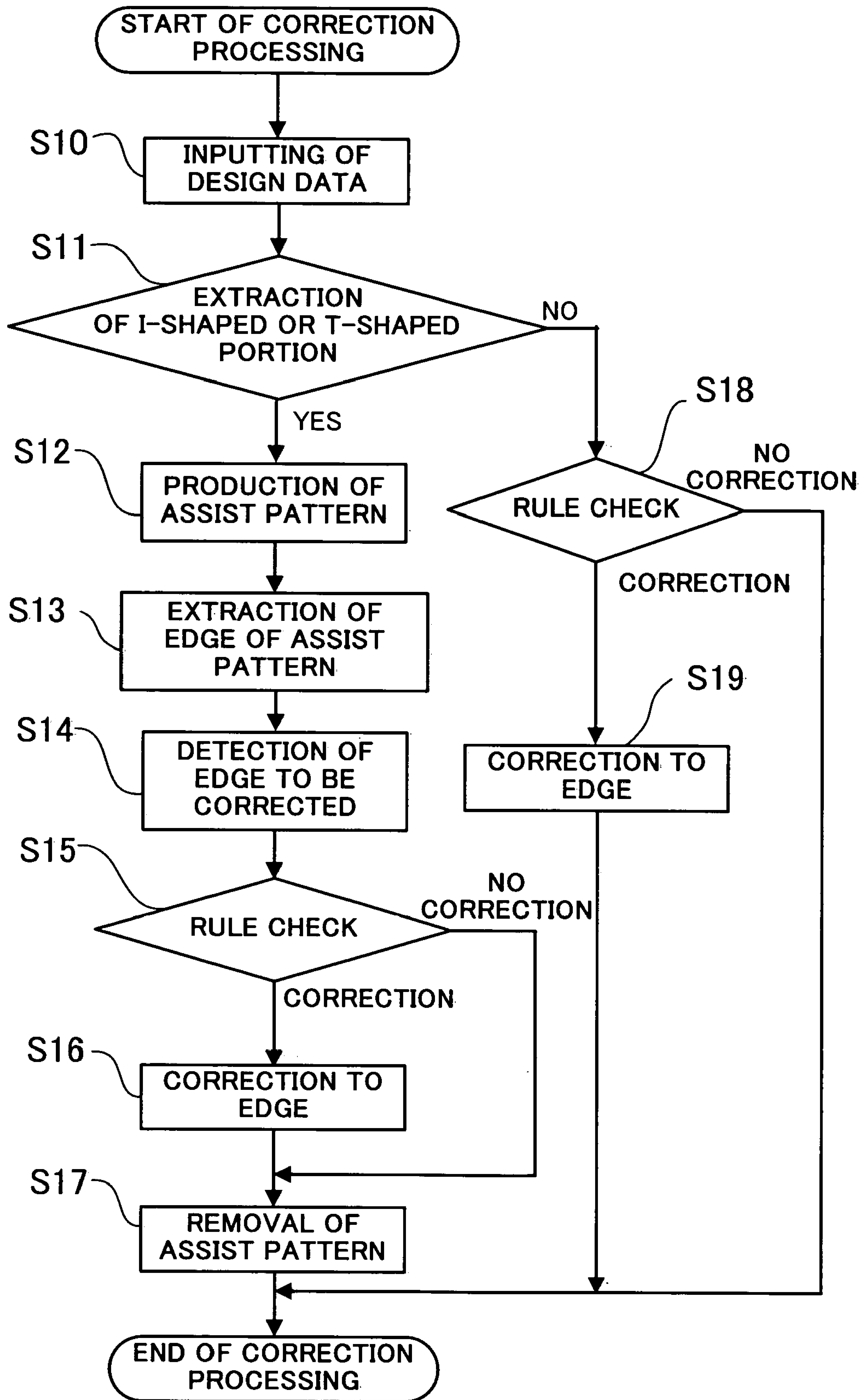

FIG. 4

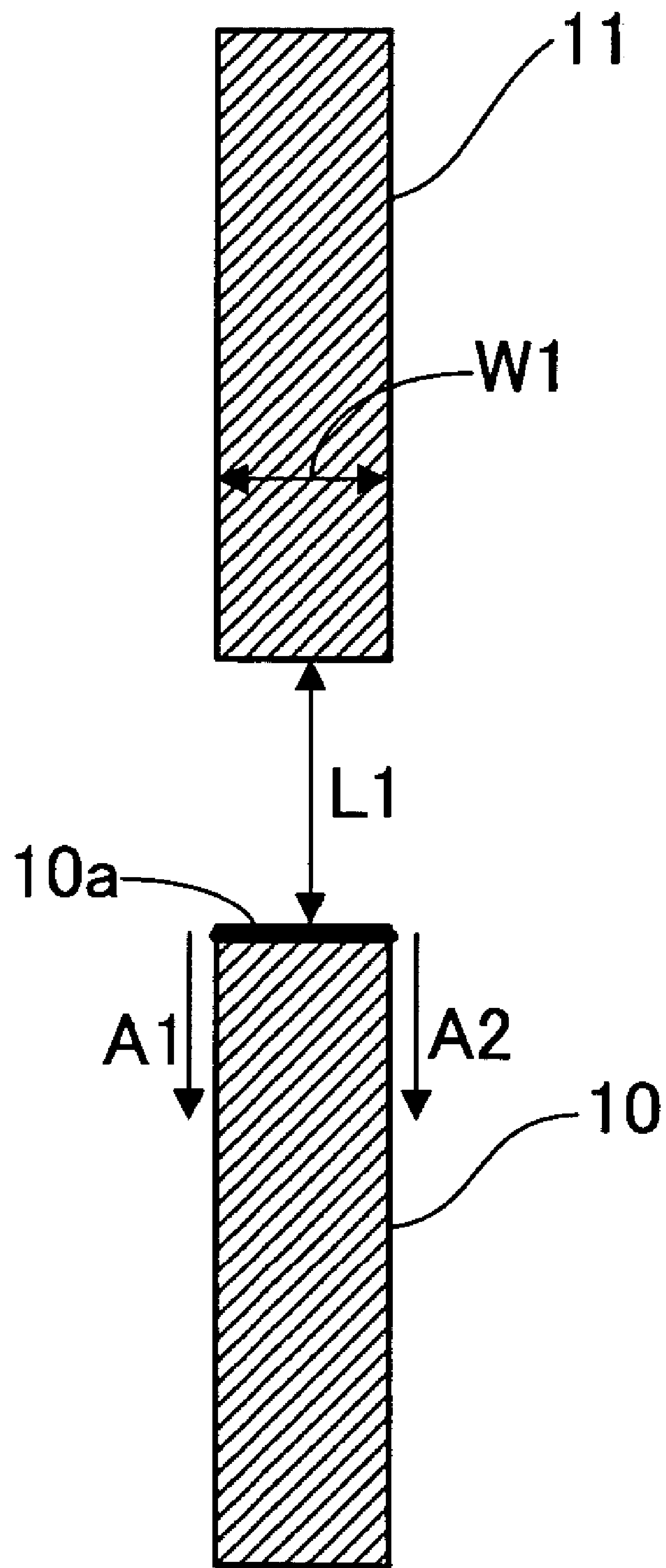

FIG. 5

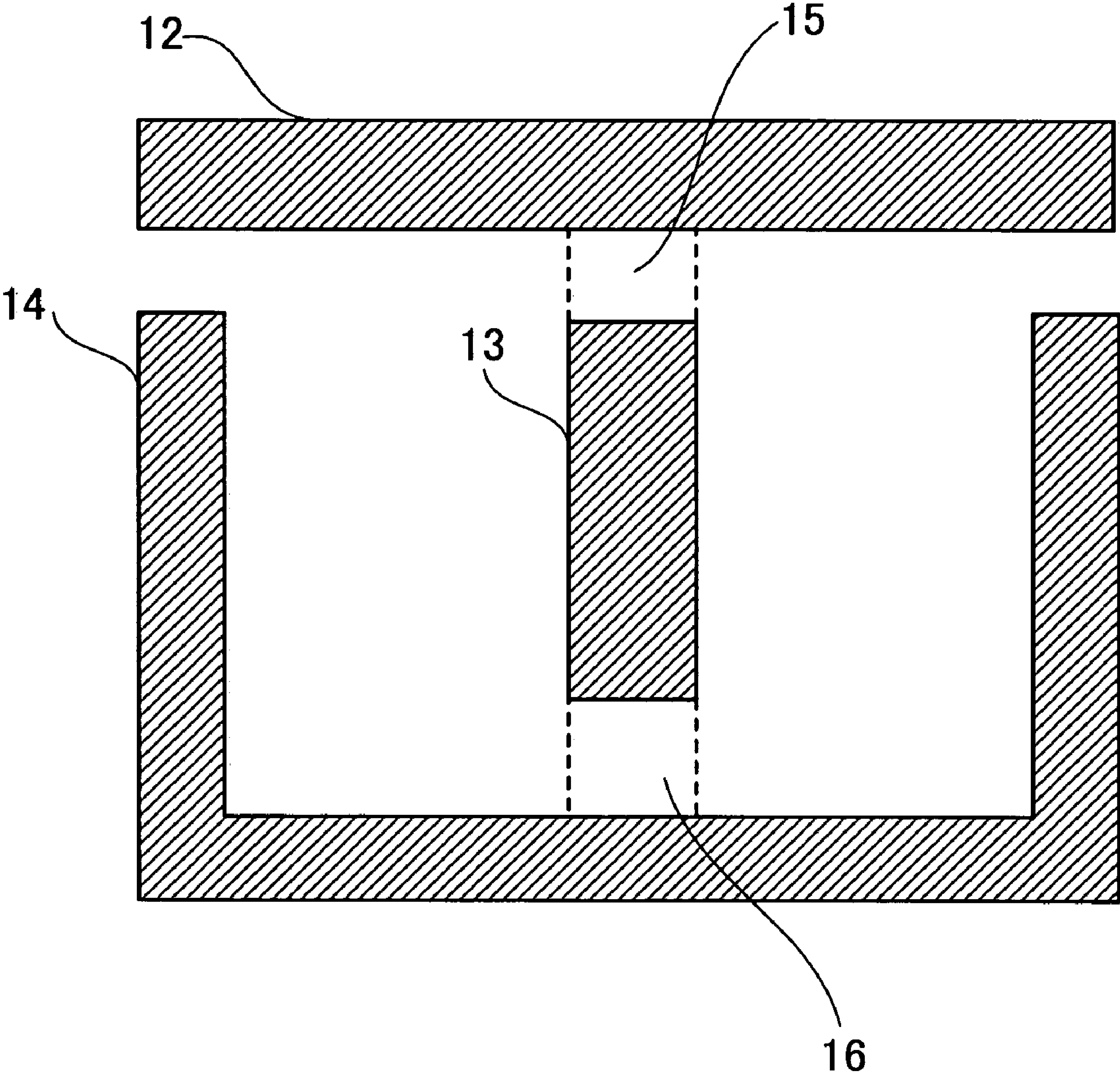

FIG. 6

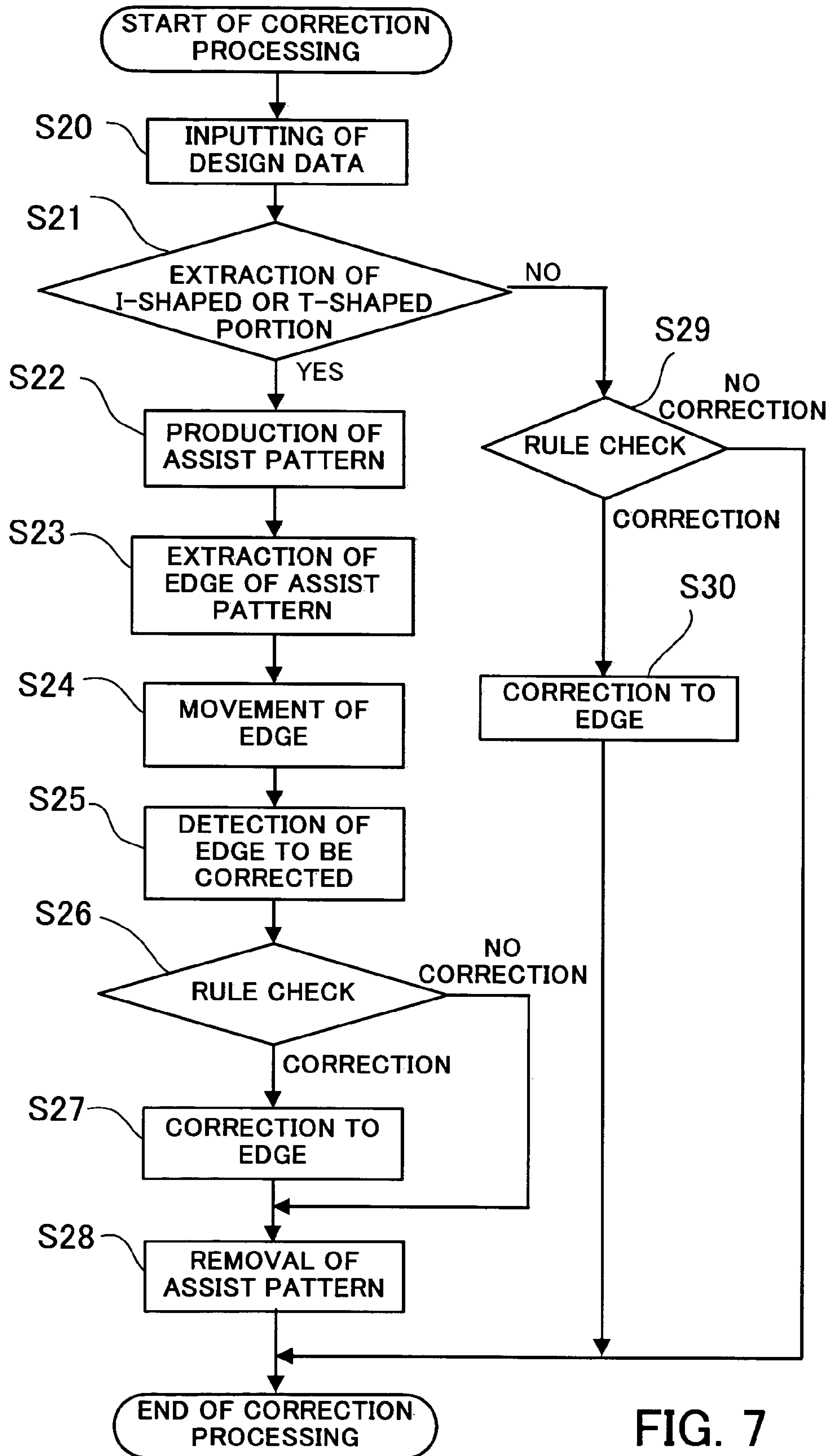

FIG. 7

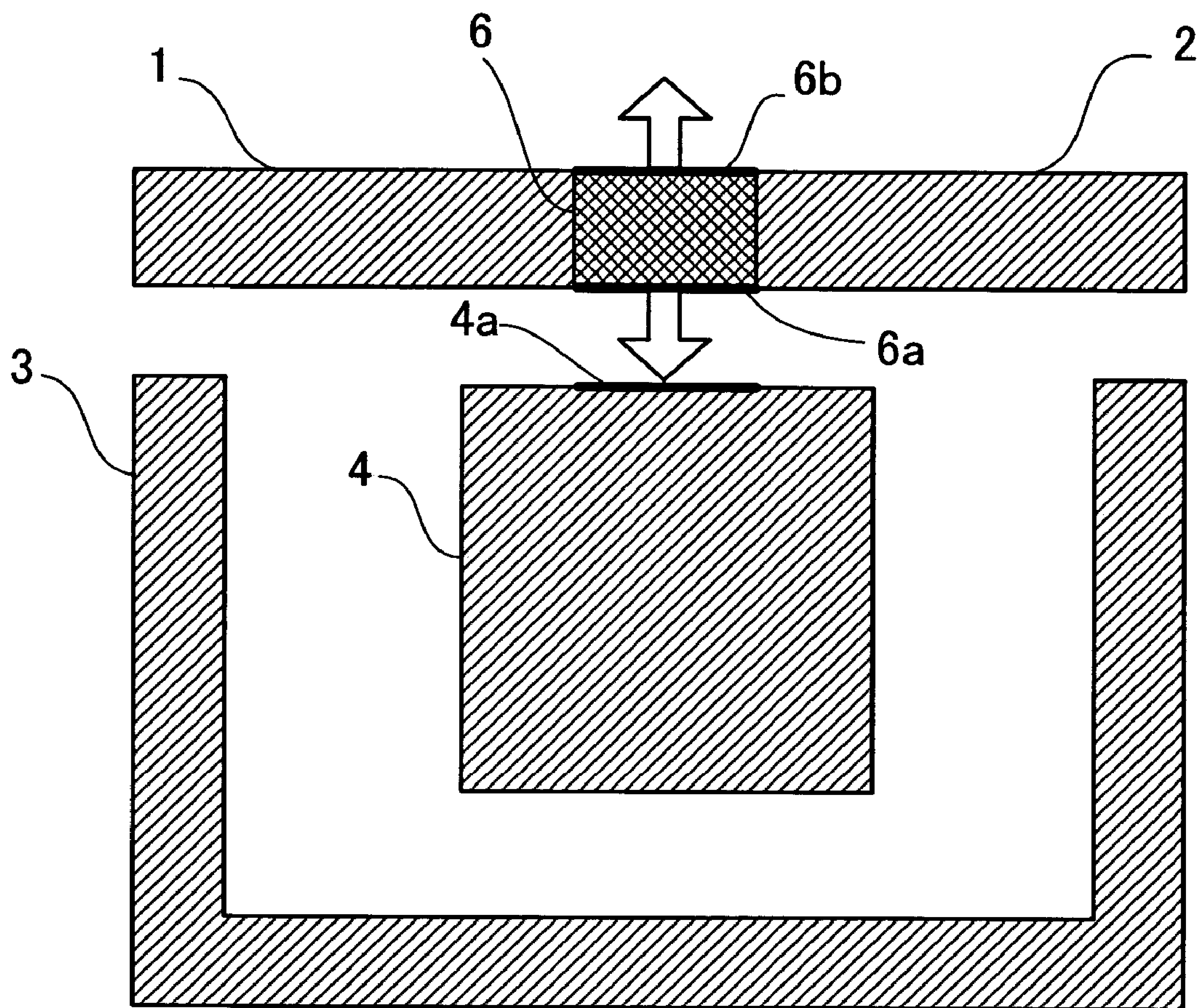

FIG. 8

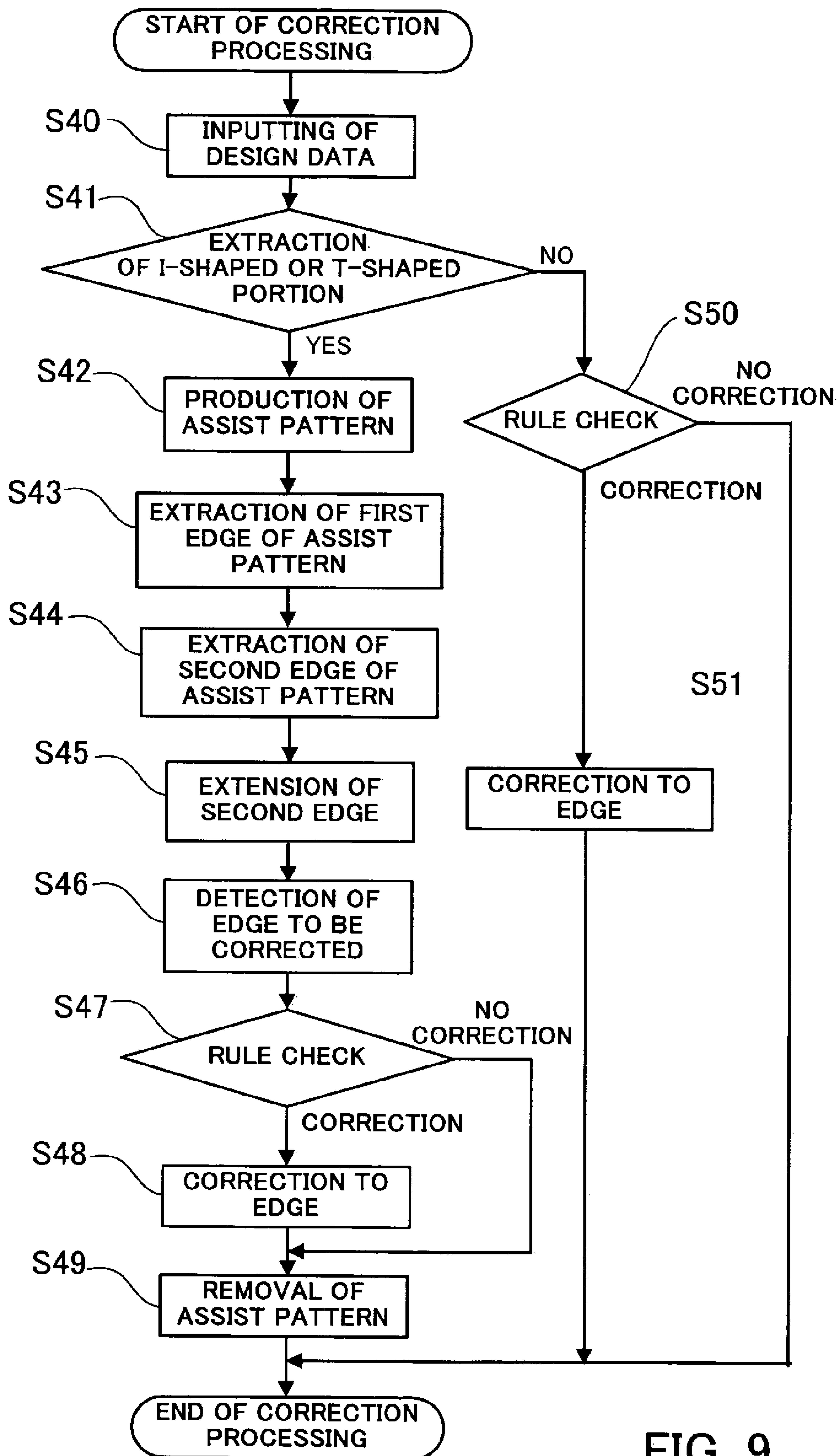

FIG. 9

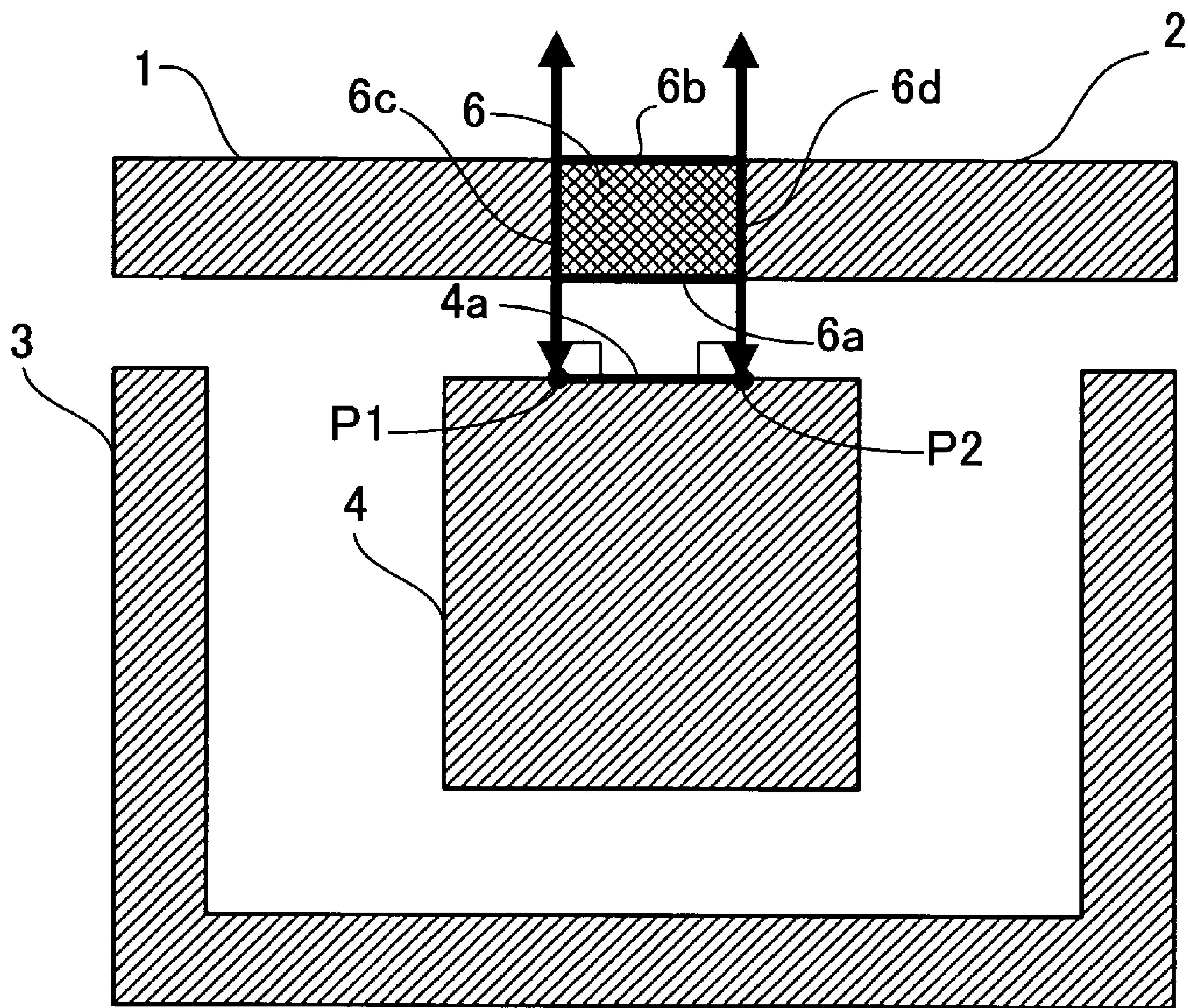

FIG. 10

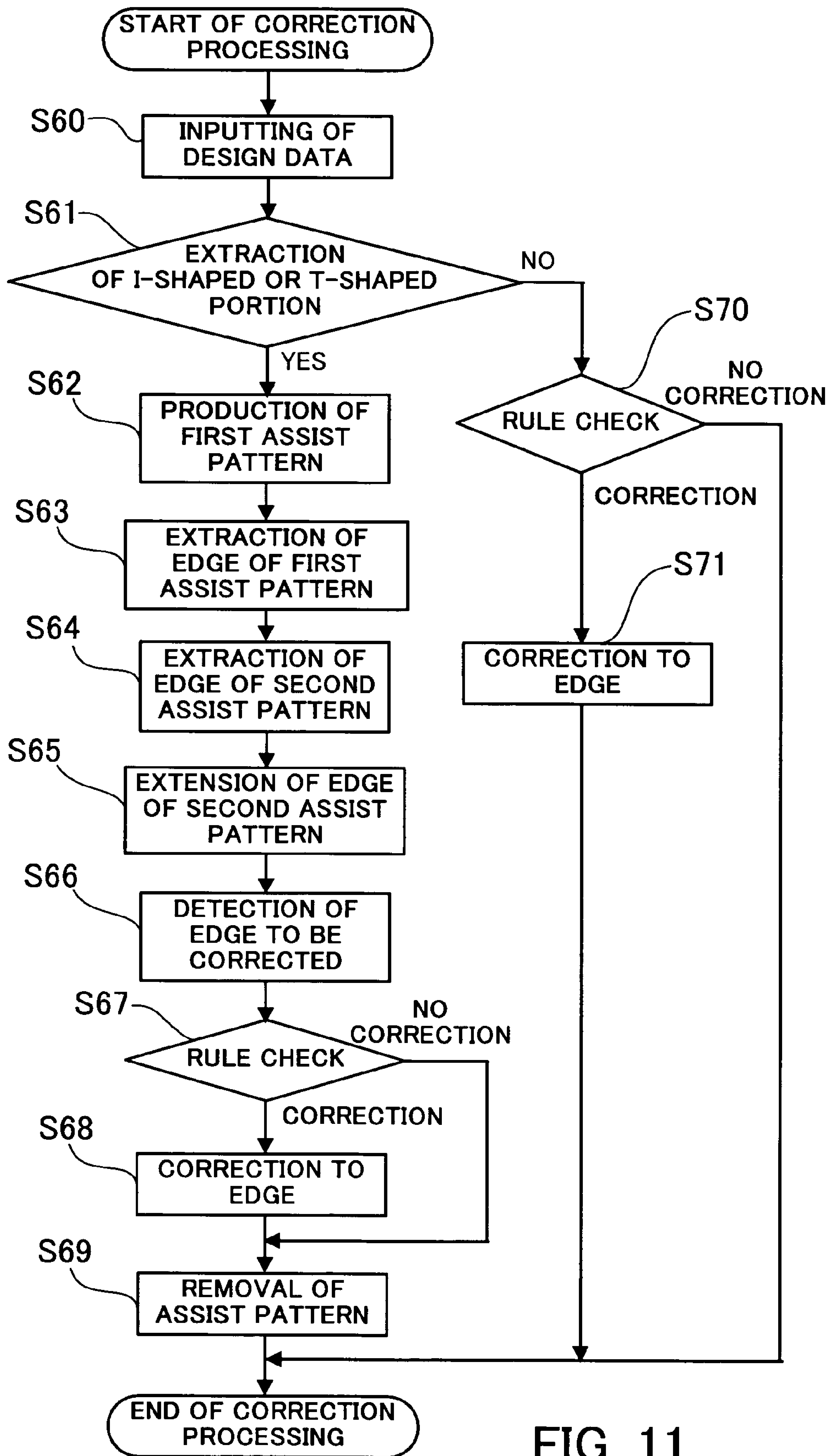

FIG. 11

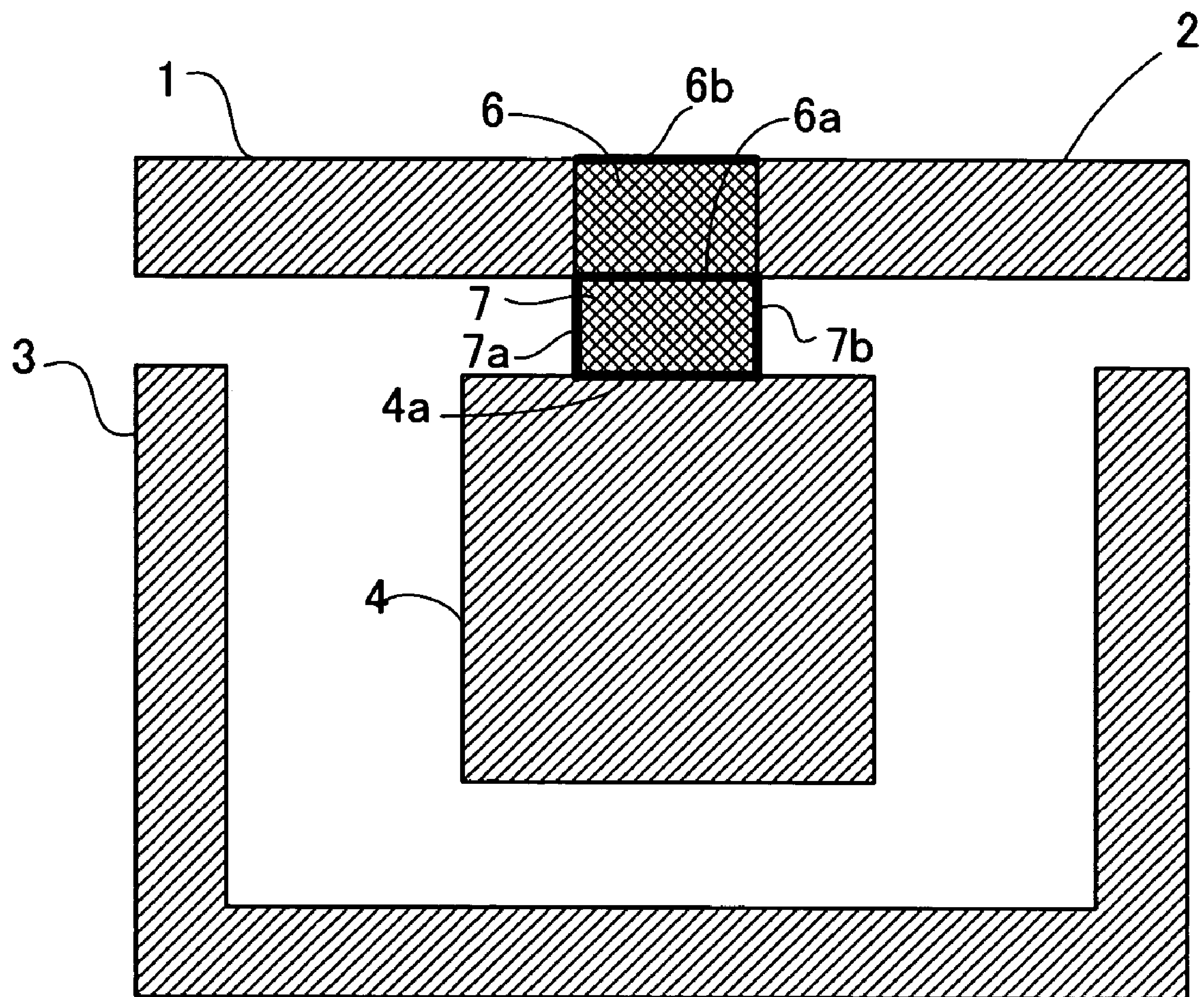

FIG. 12

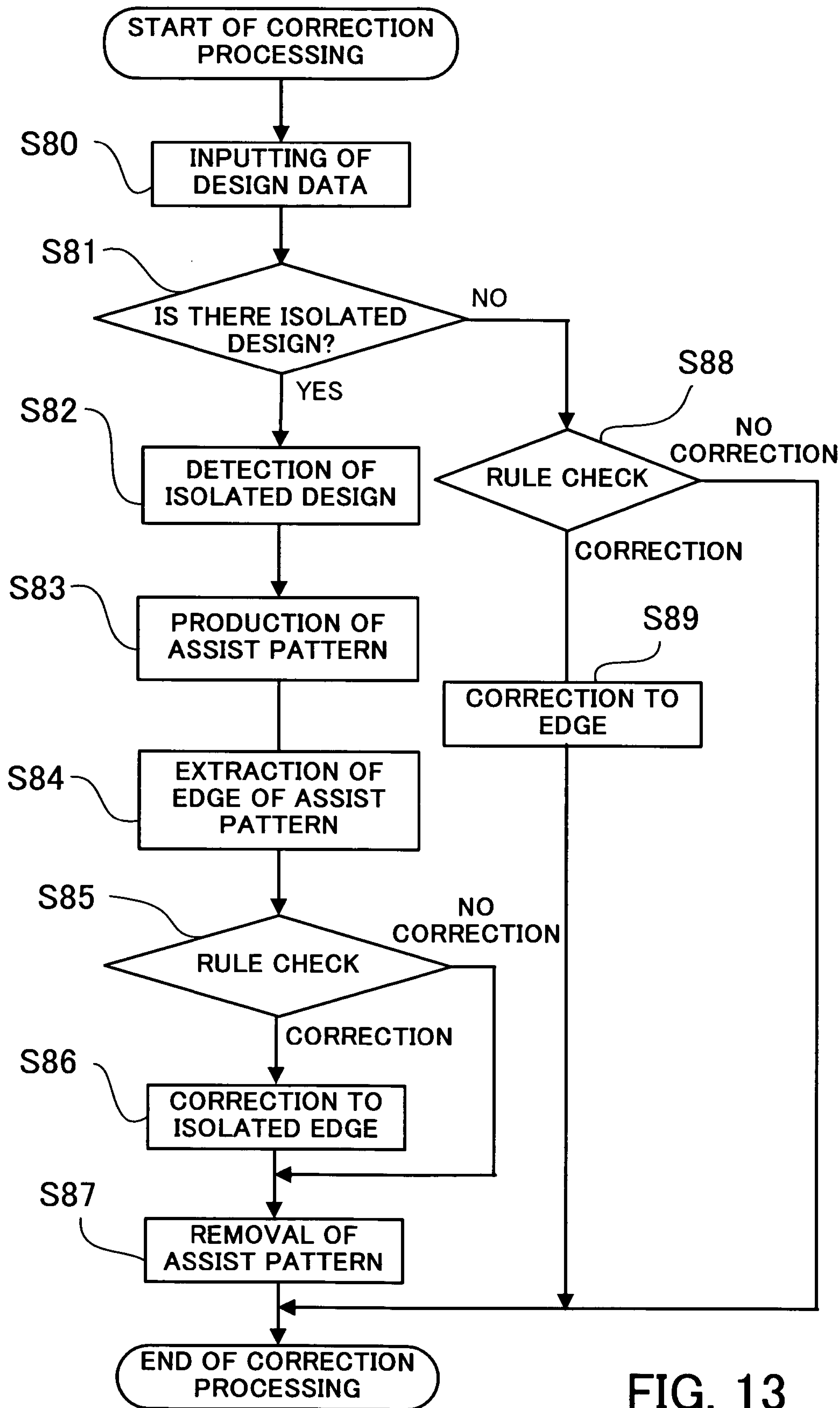

FIG. 13

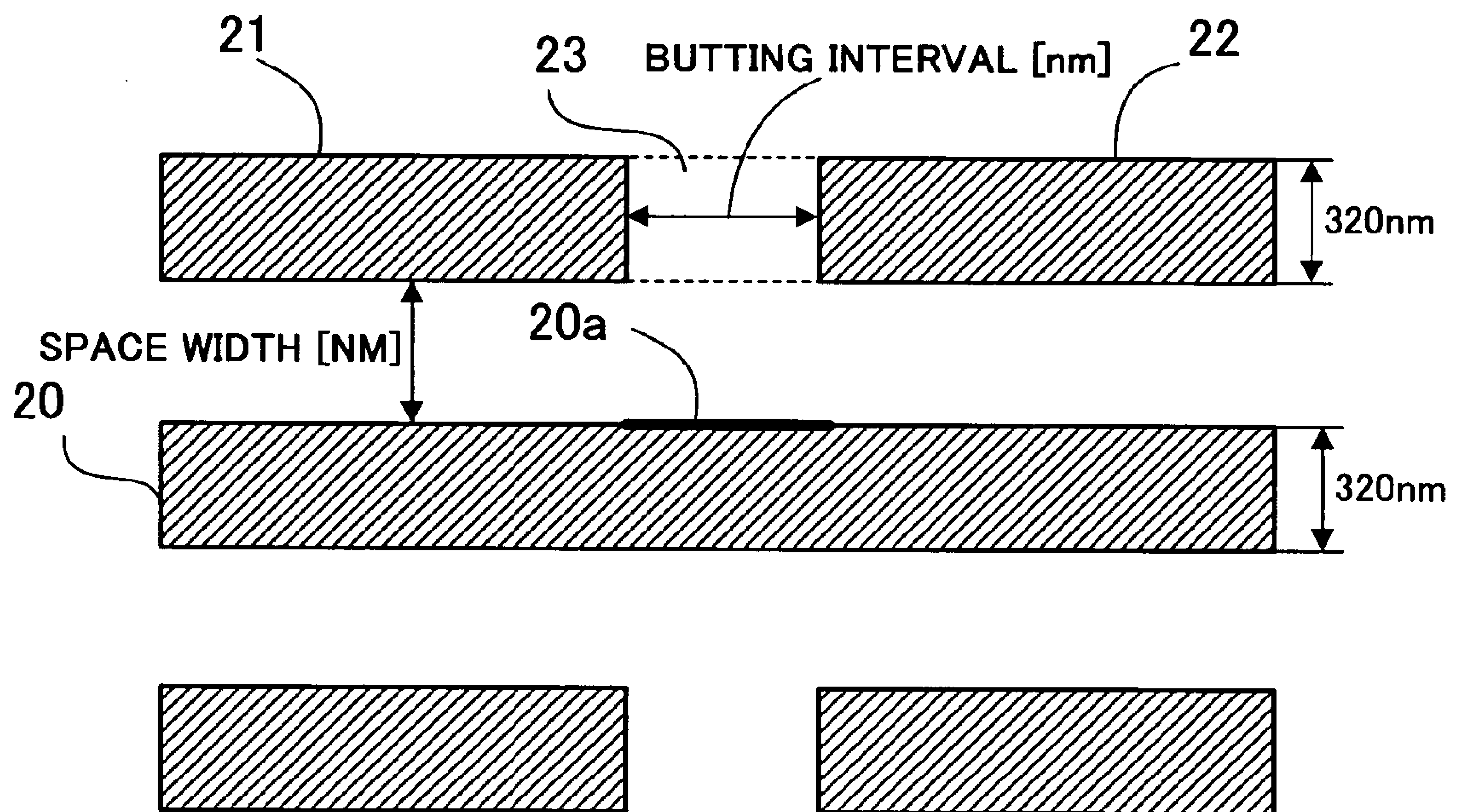

FIG. 14

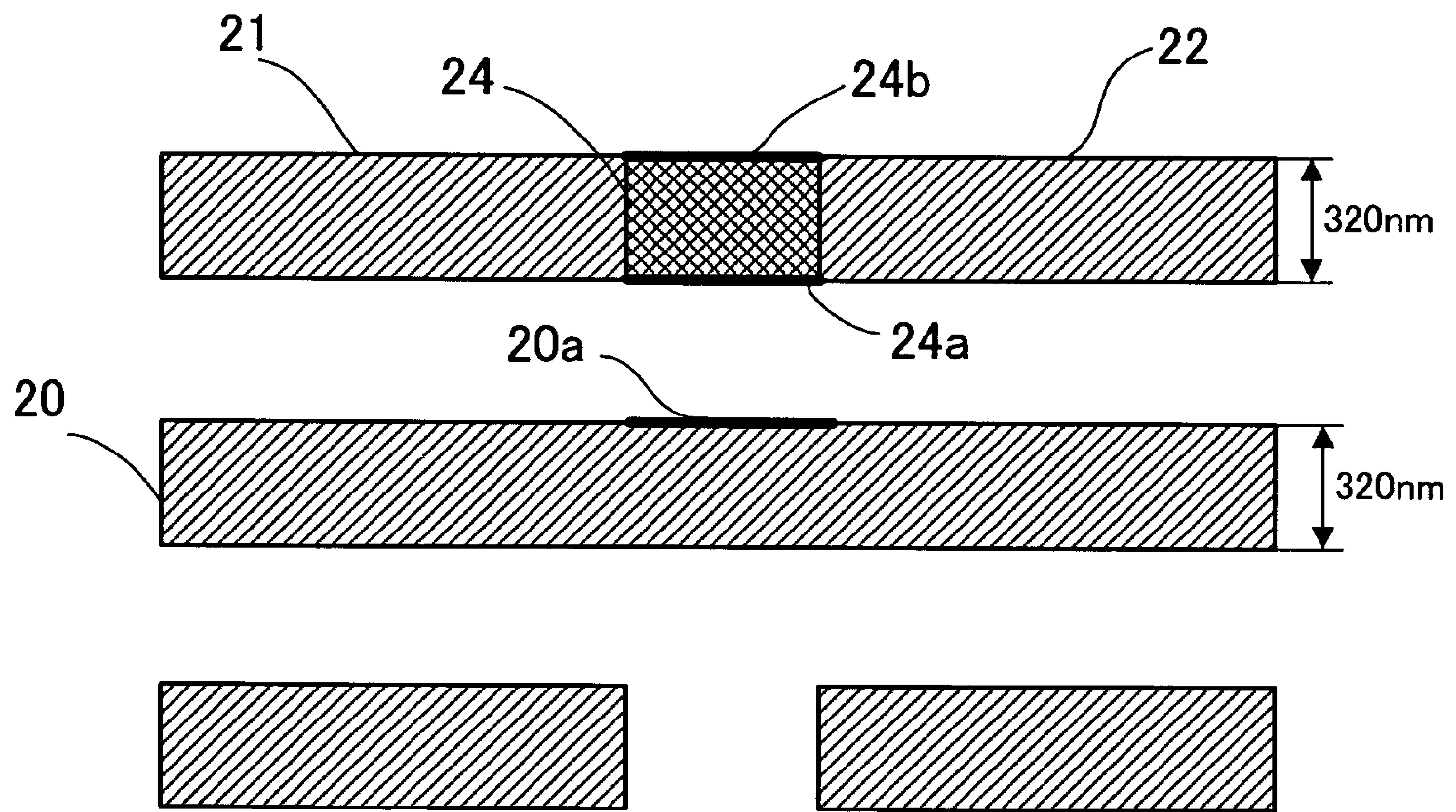

FIG. 15

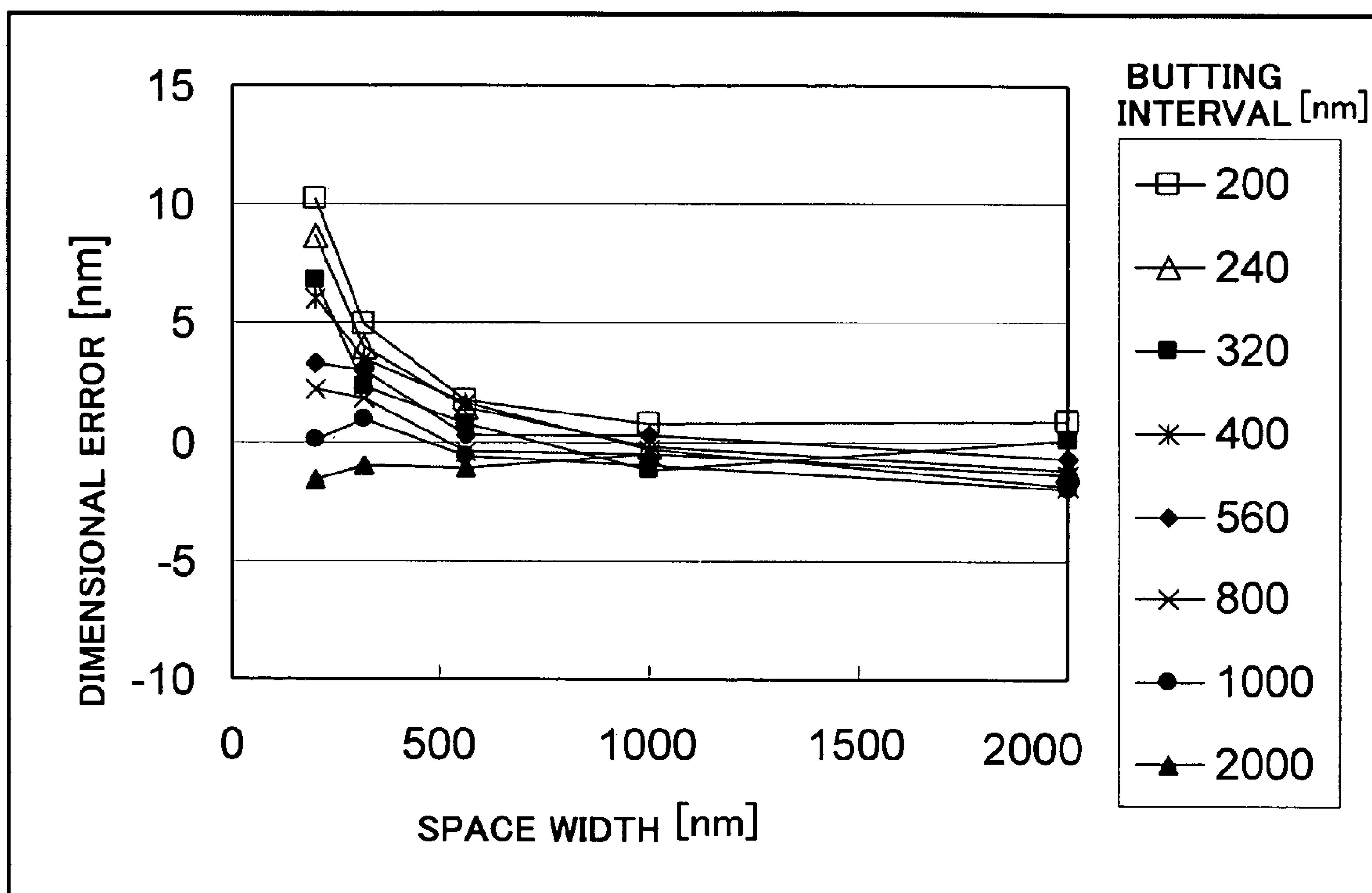

FIG. 16

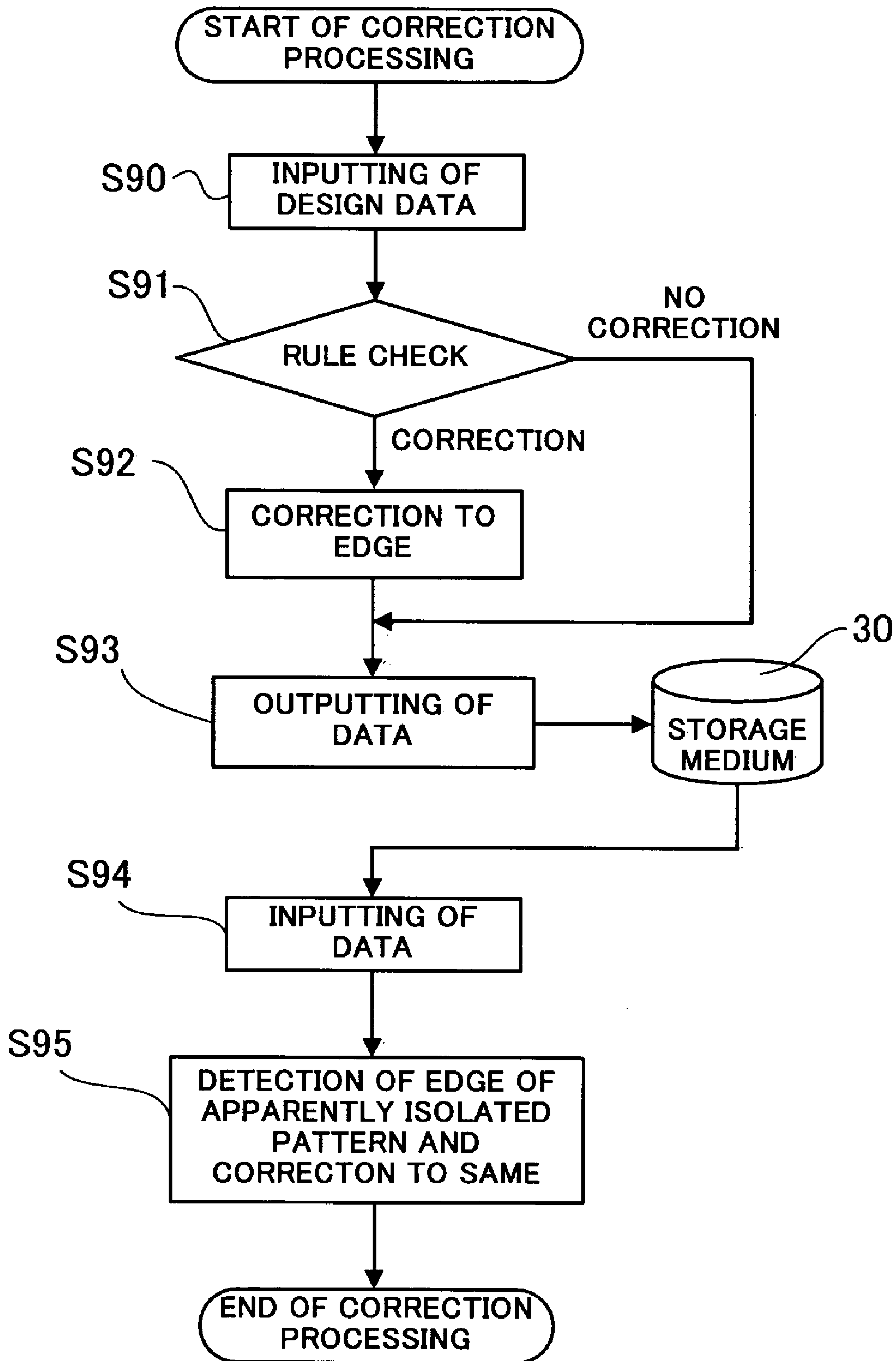

FIG. 17

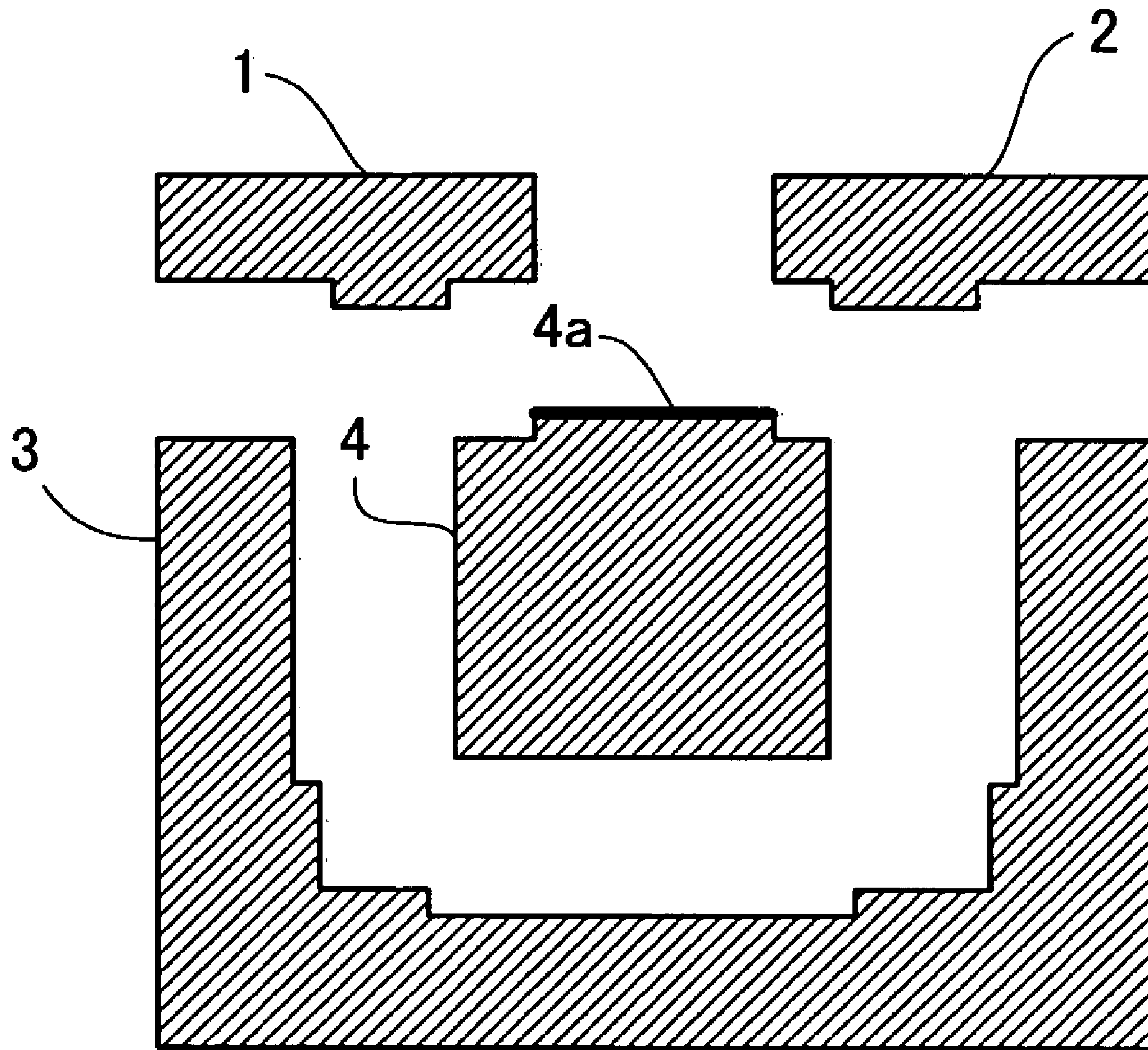

FIG. 18

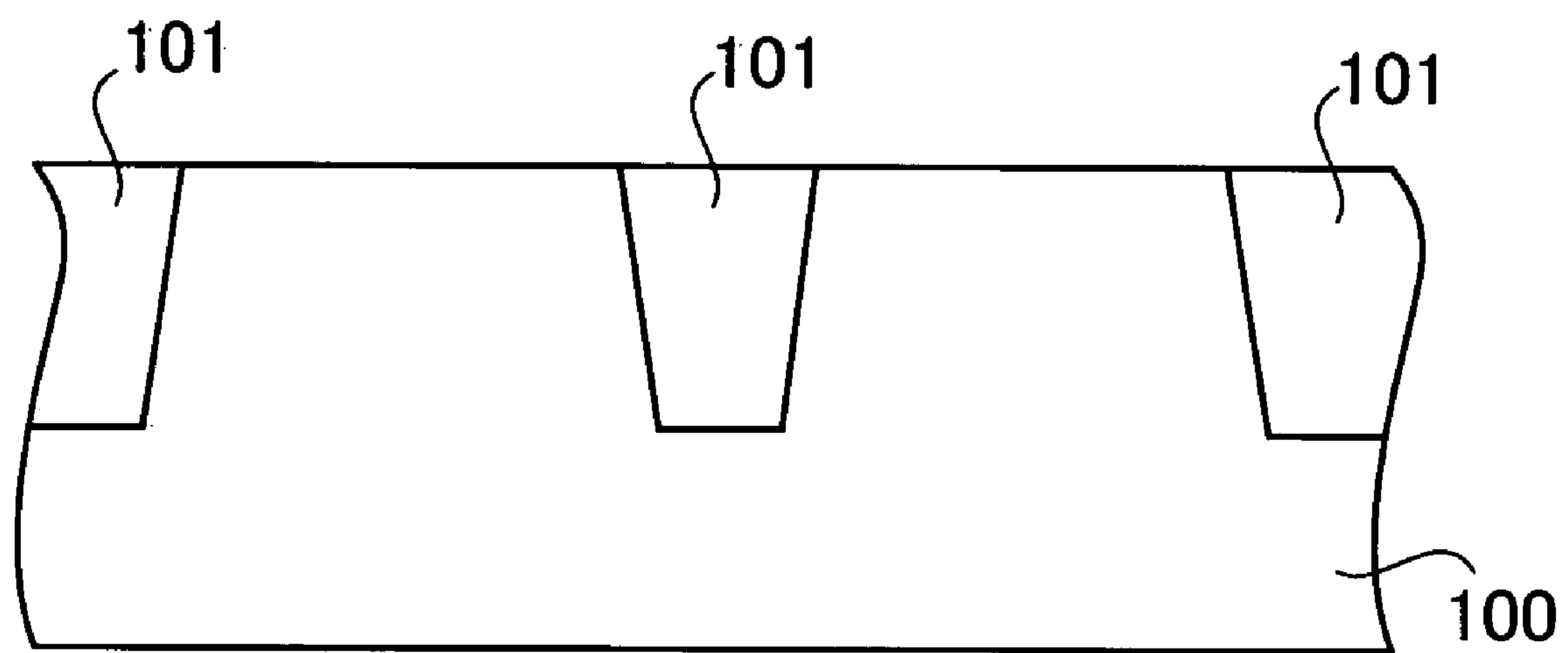

FIG. 19

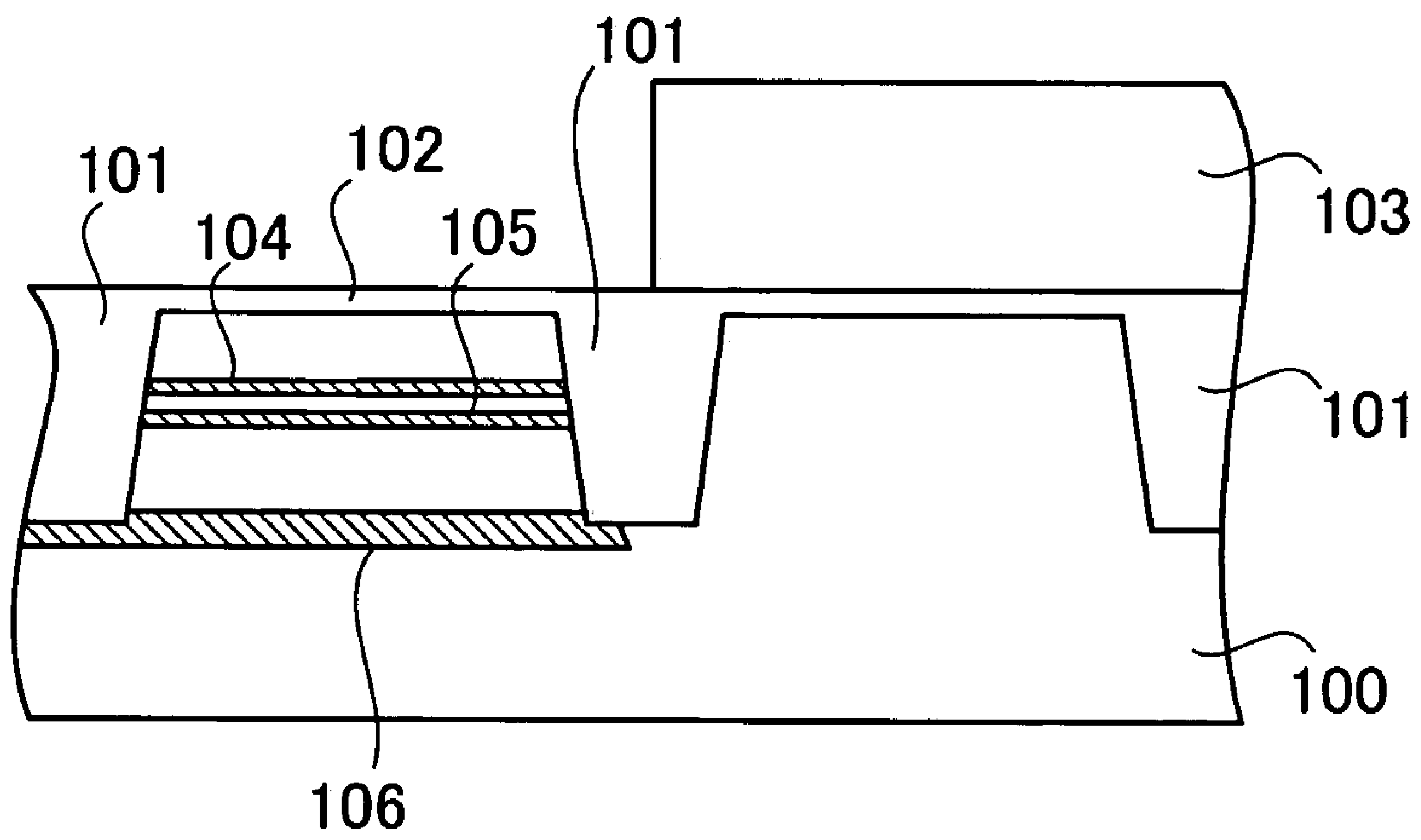

FIG. 20

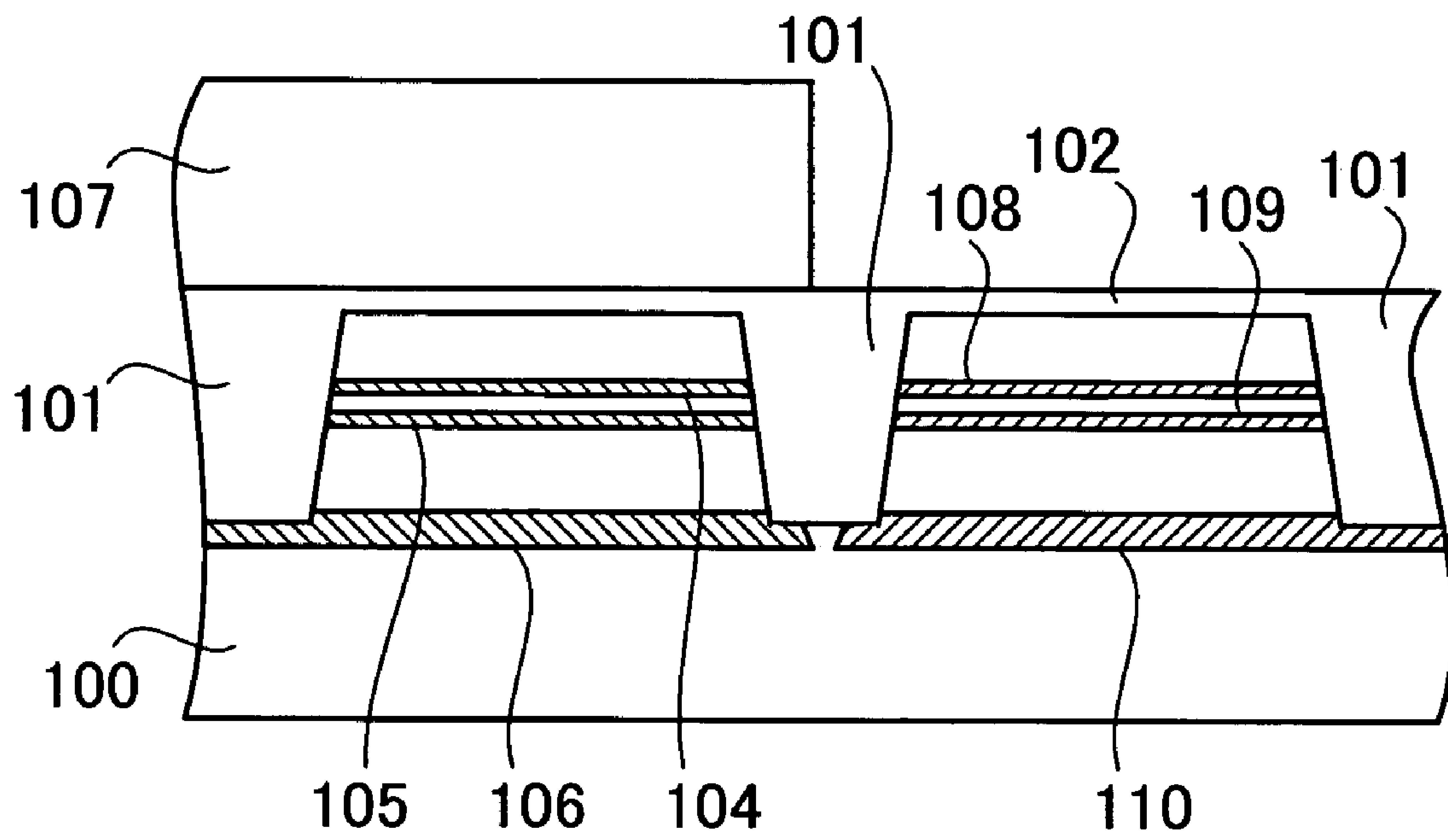

FIG. 21

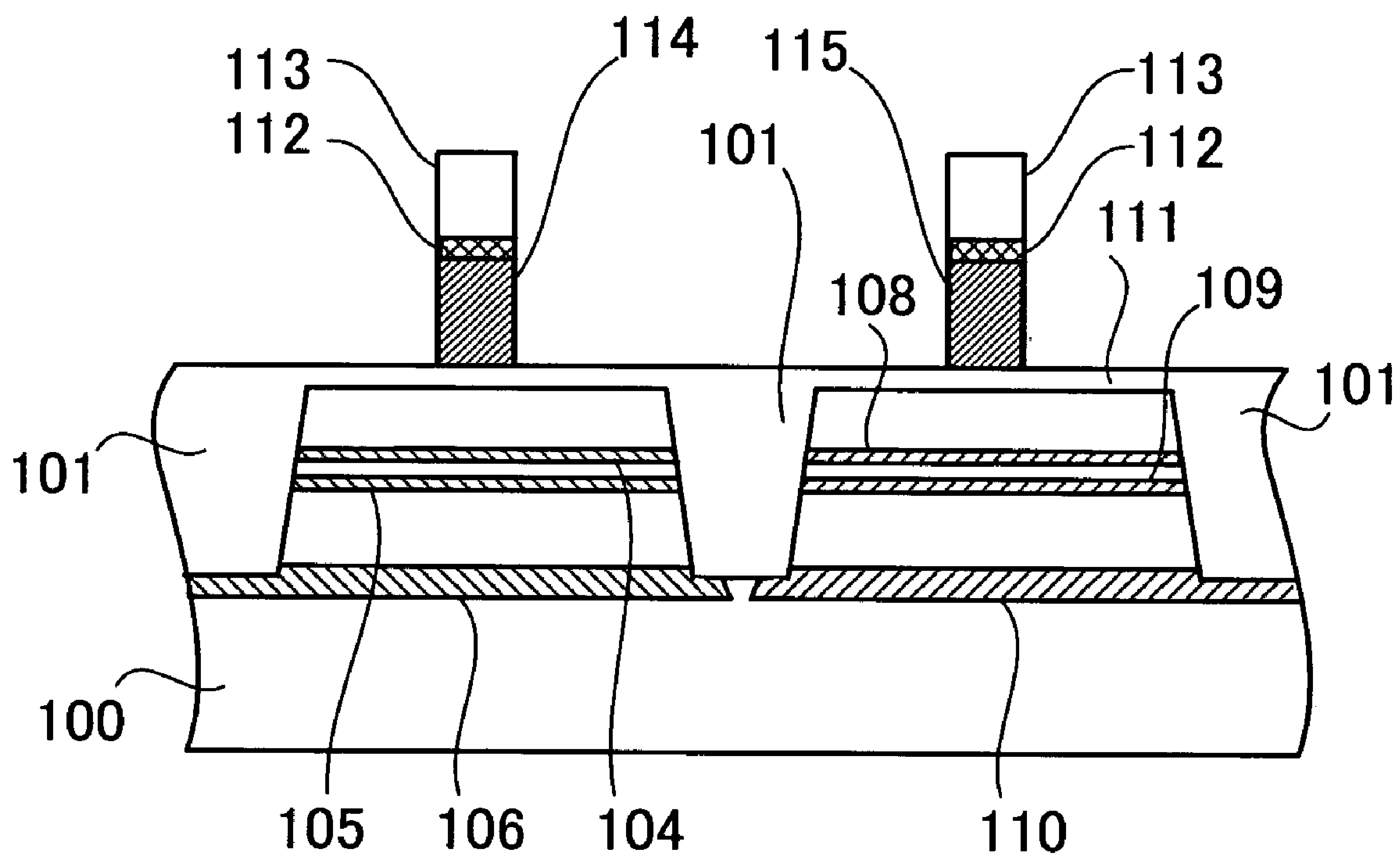

FIG. 22

METHOD FOR CORRECTING PATTERN DATA AND METHOD FOR MANUFACTURING SEMICONDUCTOR DEVICE USING SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based on, and claims priority to, Japanese Application No. 2004-379438, filed Dec. 28, 2004, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method for making a correction to pattern data and a method for manufacturing semiconductor devices, and particularly to the method for making the correction to pattern data affected by a proximity effect when a pattern is formed on a photomask or wafer and the method for manufacturing semiconductor devices using the above method.

2. Description of the Related Art

In recent years, patterns to be formed by photolithography employed in processes of manufacturing leading-edge semiconductor devices are being made fine and highly-integrated. As a result, a problem occurs in that, in the formation of a pattern with an exposure wavelength or less, due to an adverse influence by a proximity effect, a shape of a mask pattern using a photomask (hereinafter simply referred to as a "mask") does not coincide with that of a resist pattern obtained by transferring the mask pattern on a wafer.

Also, in the etching process for microfabrication of a front-end layer using a resist pattern on which the mask pattern has been transferred, due to a loading effect which leads to variations in a conversion difference caused by a difference in a pattern shape and a pattern density, a phenomenon occurs that a shape of a resist pattern does not coincide with that of a microfabricated pattern for the front-end layer obtained by the selective etching process.

To solve this problem and to obtain a pattern having a desired dimension and shape, an OPC (Optical Proximity Correction) technology in which a required amount of correction is added to mask pattern data is being employed generally in recent years. To obtain an effect of the OPC technology, it is necessary that a difference between a finally-obtained dimension of a mask pattern and a dimension in mask pattern data is made as small as possible. In the formation of a mask to be used for manufacturing recent leading-edge semiconductor devices in particular, very extremely high accuracy in its linearity, in difference of pattern density, or the like is required. However, at present, it is difficult to satisfy the demand for such extremely high accuracy only by improvement of mask producing processes. This holds true for manufacturing a mask using a nega-type resist in particular. The process of manufacturing a mask using a nega-type resist is employed when a mask for a gate layer requiring extremely high accuracy is produced, thus presenting a serious problem.

A method for correcting such a dimensional error by using the OPC technology is disclosed in, for example, Japanese Unexamined Patent Publication No. 2003-195478. In this method, so-called rule-based OPC technology is applied to a mask process. According to this method, a correlation between a space dimension among adjacent patterns and a dimensional change in a pattern itself is first determined and, by using this result, a necessary dimensional correction is made to mask pattern data.

However, the conventional method disclosed in Japanese Unexamined Patent Publication No. 2003-195478 has a problem that the process in the method has a favorable correcting effect on a simple pattern if including only a line pattern and space, but adversely affects a pattern having a complicated layout.

SUMMARY OF THE INVENTION

In view of the foregoing, it is an object of the present invention to provide a method for correcting pattern data which is capable of making a proper correction to data of a pattern having a complicated layout.

It is another object of the present invention to provide a method for manufacturing a semiconductor device which enables a desired microfabricated pattern to be obtained.

According to one aspect of the present invention, there is provided a pattern data correcting method for making a correction to pattern data affected by a proximity effect when a pattern is formed on a photomask or wafer according to design data for a semiconductor device, including the steps of: detecting, according to the design data, a space portion being placed on the photomask or wafer and having a specified size occurring between patterns facing each other in a first direction; producing a pattern data corresponding to an assist pattern that fills the space portion; detecting an edge to be corrected in a position being opposite to an edge of the assist pattern extending in a second direction between the patterns facing each other, out of framing portions of the pattern being placed in parallel and near to the assist pattern; making a correction being independent of a correction to be made to other edge of the framing portions to the detected edge to be corrected; and removing the assist pattern.

According to another aspect of the present invention, there is provided a pattern data correcting method for making a correction to pattern data affected by a proximity effect when a pattern is formed on a photomask or wafer according to design data for a semiconductor device, including the steps of: extracting a region, as an isolated edge, in which a space portion occurring between second patterns facing each other exists within a specified distance in a first direction, out of edges in framing portions of a first pattern; producing pattern data corresponding to an assist pattern that fills the space portion; extracting an edge of the assist pattern extending between the first and second patterns facing each other in a second direction; making a correction to data of the isolated edge according to a length of the edge of the assist pattern and an interval between the assist pattern and the isolated edge; and removing the assist pattern.

According to still another aspect of the present invention, there is provided a method for manufacturing a semiconductor device including the step of: performing exposures by using a photomask formed, with an aim of making a correction to pattern data affected by a proximity effect when a pattern is formed on a photomask or wafer according to design data for a semiconductor device, by detecting, according to the design data, a space portion being placed on the photomask or wafer and having a specified size occurring between patterns facing each other in a first direction, by producing a pattern data corresponding to an assist pattern that fills the space portion, by detecting an edge to be corrected in a position being opposite to an edge of the assist pattern extending in a second direction between the patterns facing each other, out of framing portions of the pattern

being placed in parallel and near to the assist pattern, by making a correction being independent of a correction to be made to other edge of the framing portion to the detected edge to be corrected, and by removing the assist pattern.

According to still another aspect of the present invention, there is provided a method for manufacturing a semiconductor device including the step of: performing exposures by using a photomask formed, with an aim of making a correction to pattern data affected by a proximity effect when a pattern is formed on a photomask or wafer according to design data for a semiconductor device, by extracting a region, as an isolated edge, in which a space portion occurring between second patterns facing each other exists within a specified distance in a first direction, out of edges in framing portions of a first pattern, by producing pattern data corresponding to an assist pattern that fills the space portion, by extracting an edge of the assist pattern extending between the first and second patterns facing each other in a second direction, by making a correction to data of the isolated edge according to a length of the edge of the assist pattern and an interval between the assist pattern and the isolated edge and by removing the assist pattern.

The above and other objects, features and advantages of the present invention will become apparent from the following description when taken in conjunction with the accompanying drawings which illustrate preferred embodiments of the present invention by way of example.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows schematically a method for correcting pattern data according to an embodiment of the present invention.

FIG. **2** shows an example of a pattern.

FIG. **3** shows a state in which an assist pattern has been produced.

FIG. **4** shows a flowchart indicating a flow of processes of a pattern data correcting method of a first embodiment of the present invention.

FIG. **5** shows one example to define an I-shaped or T-shaped portion.

FIG. **6** shows an example of patterns that are recognized as a T-shaped portion.

FIG. **7** shows a flowchart indicating a flow of processes of a pattern data correcting method of a second embodiment of the present invention.

FIG. **8** shows a state in which an edge of an assist pattern is moved.

FIG. **9** shows a flowchart indicating a flow of processes of a pattern data correcting method of a third embodiment of the present invention.

FIG. **10** shows a state in which an edge to be corrected is detected by extending a second edge of an assist pattern.

FIG. **11** shows a flowchart indicating a flow of processes of pattern data correcting method of a fourth embodiment of the present invention.

FIG. **12** shows an example of a produced second assist pattern.

FIG. **13** shows a flowchart indicating a flow of processes of a pattern data correcting method of a fifth embodiment of the present invention.

FIG. **14** shows a state in which an isolated edge is detected.

FIG. **15** shows a state in which an assist pattern is produced in a space portion which faces an isolated edge to be corrected.

FIG. **16** shows dependency of a pattern on a space width and a butting interval.

FIG. **17** shows a flowchart indicating a flow of processes of a pattern data correcting method of a sixth embodiment of the present invention.

FIG. **18** shows an example of a pattern corrected according to space and line dimensions.

FIG. **19** shows a cross-sectional view explaining one process of manufacturing a semiconductor (first).

FIG. **20** shows a cross-sectional view explaining one process of manufacturing a semiconductor (second).

FIG. **21** shows a cross-sectional view explaining one process of manufacturing a semiconductor (third).

FIG. **22** shows a cross-sectional view explaining one process of manufacturing a semiconductor (fourth).

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** shows schematically a method for correcting pattern data according to an embodiment of the present invention.

FIG. **2** shows an example of a pattern.

A method is described for making a correction to pattern data affected by a proximity effect when such a pattern as shown in FIG. **2** is formed on a photomask below.

When a proximity-effect correction is made by the conventional method to design data having patterns **1**, **2**, **3**, and **4** as shown in FIG. **2**, since other pattern does not exist in a direction opposite to, for example, the edge **4***a* of the pattern **4**, the pattern **4** is recognized as an isolated pattern according to an ordinary proximity-effect correction rule (Line & Space), no correction is made to the pattern **4**. However, if there are patterns each having a complicated layout in a dense state, etching progress less easily in this area and, therefore, a pattern dimension of the edge **4***a* becomes larger than a desired dimension as in the case of other edges. Due to this, no proper correction is made and such dimensional errors occur.

In the pattern data correcting method shown in FIG. **1**, such design data as having the patterns **1**, **2**, **3**, and **4** shown in FIG. **2**, is read to detect a space portion **5** with a specified size occurring among patterns facing one another (Step S**1**). The space portion **5** is detected according to a designated rule (described in detail later).

Next, pattern data corresponding to an assist pattern that fills the detected space portion **5** is produced (Step S**2**). FIG. **3** shows a state in which an assist pattern has been produced. As shown in FIG. **3**, the assist pattern **6** is produced in the space portion **5** between the patterns **1** and **2**. The edge **4***a* positioned opposite to edges **6***a* and **6***b* of the assist pattern **6** extending in a direction of a distance between the patterns **1** and **2** facing each other, out of framing portions of the pattern **4** placed in parallel and near to the assist pattern **6**, is detected as an edge to be corrected (Step S**3**). A correction is made to the detected edge **4***a* independently of the correction to be made to other edge in the framing portions of the pattern **4** (Step **4**). More specifically, the correction is made to the detected edge **4***a* by applying a correction value corresponding to a distance from the assist pattern **6** or to a distance between the patterns **1** and **2** (described in detail later). Finally, the assist pattern **6** is removed (Step S**5**).

By using the pattern data correcting method described above, a proper correction can be made to even an edge which is ordinarily handled as an isolated pattern and to which no proper correction is made.

The pattern data correcting method is explained in detail below. The pattern data correcting method described below is realized by operations of a CPU (Central Processing Unit) according to an algorithm of software installed in, for example, a computer.

FIG. **4** shows a flowchart indicating a flow of processes of the pattern data correcting method of a first embodiment of the present invention. First, after design data to produce an original drawing is input (Step S**10**), in order to detect the space portion **5** as shown in FIG. **2**, a portion in which patterns face each other in an I-shaped manner or in a T-shaped manner is extracted (Step S**11**). More specifically, patterns placed as shown in FIG. **5** or **6** are defined respectively as an I-shaped portion or T-shaped portion and are extracted.

FIG. **5** shows one example to define an I-shaped or T-shaped portion.

First, an end **10***a* of a pattern **10** having a specified length or more in directions of arrows A**1** and A**2** under a condition is recognized. When another pattern **11** exists within a specified distance L**1** (for example, within 2000 nm), the pattern **11** and pattern **10** facing each other are recognized as an I-shaped portion. Moreover, if a width W**1** of the pattern **11** is larger than a value, the pattern **11** and pattern **10** facing each other is recognized as a T-shaped portion. In the example shown in FIG. **2**, the patterns **1** and **2** facing each other are recognized as an I-shaped portion.

FIG. **6** shows an example of patterns that are recognized as a T-shaped portion. In the example, the T-shaped portion formed by patterns **12** and **13** and the T-shaped portion formed by patterns **13** and **14** are extracted and space portions **15** and **16** occurring in areas in which the patterns **12** and **13** face each other and the patterns **13** and **14** face each other are detected.

Moreover, if neither the I-shaped nor T-shaped portion is extracted in the process in Step S**11** in FIG. **4**, the routine proceeds to Step S**18**. When the I-shaped or T-shaped portion is extracted, an assist pattern (see FIG. **3**) that fills the space portion detected in its I-shaped or T-shaped portion is produced (Step S**12**). Furthermore, pattern data, by being defined by a layer (variable or the like) being different from design data of an original drawing (real pattern), can be easily erased at time of actual production of a mask pattern or be easily differentiated from the design data for a real pattern.

Next, the edge of the assist pattern extending in a direction between patterns facing each other is extracted (Step S**13**). Here, in the assist pattern **6** as shown in FIG. **3**, edges **6***a* and **6***b* extending in a direction of a distance (hereinafter called a butting interval) between the patterns **1** and **2** are detected.

Thereafter, the edge positioned opposite to edges of the assist pattern extending in a direction of a distance between the patterns facing each other, out of framing portions of the pattern being placed in parallel and near to the detected assist pattern is detected as an edge to be corrected (Step S**14**). More specifically, by detecting a difference between pattern data of the assist pattern with layer definition performed and real pattern data and, as shown in FIG. **3**, by extracting an area positioned opposite to the edge **6***a* and having the same length as that of the edge **6***a*, out of framing portions of the pattern **4** being the real pattern being placed in parallel and near to the assist pattern **6**, the edge **4***a* to be corrected is detected.

Next, after a rule check is made, whether or not a correction is made to the detected edge to be corrected is judged (Step S**15**). In this rule check, unlike in the case of the ordinary proximity-effect correction rule (Line & Space), for example, in the case of the pattern data shown in FIG. **3**, whether or not the correction is made to the edge **4***a* is judged according to a length of the edge **6***a* (that is; butting interval) and an interval (space width) between the edge **6***a* and the edge **4***a* of the pattern data **4** facing each other.

If it is judged that the edge to be corrected requires a correction, a correction value is determined according to a butting interval and a space width to make the correction to the edge **4***a* (Step S**16**). Here, the correction may be made by referring to a table in which correction values predetermined according to the butting interval and the space width are stored. Thereafter, the produced assist pattern is removed (Step S**17**) and the correction processing is terminated. Moreover, if it is judged, for example, due to the large space width and butting interval, that the edge to be corrected requires no correction, the correction is not made and, after the completion of the process in Step S**17**, the correction processing is terminated.

On the other hand, in the process in Step S**11**, when an I-shaped or T-shaped portion that can meet conditions is not detected, whether or not a correction is made is judged according to the ordinary proximity-effect correction rule (Line & Space)(Step S**18**) and, if the correction is to be made, a correction value is determined and according to space and line dimensions and the correction is made to the edge (Step S**19**). If it is judged that no correction is required, the correction processing is terminated without making the correction.

Thus, by extracting a portion in which patterns face each other in an I-shaped or T-shaped manner under a specified condition, the space portion **5** that influences on the edge **4***a* as shown in FIG. **2** can be detected effectively. By making a correction being independent of a correction to be made to other edge in framing portions of the pattern **4**, to the edge **4***a*, a proper correction can be made even to data of a pattern having a complicated layout and being affected by a proximity effect.

Next, a method for correcting pattern data of a second embodiment is explained. FIG. **7** shows a flowchart indicating a flow of processes of a pattern data correcting method of the second embodiment of the present invention. The processes in Steps S**20** to S**23** in the second embodiment are the same as those shown in Steps S**10** to S**13** in FIG. **4** in the pattern data correcting method of the first embodiment. In the second embodiment of the present invention, the process in Step S**24** is provided in which an edge of the assist pattern extracted in Step S**23** is moved so as to be in contact with a pattern being placed in parallel and near to the assist pattern.

FIG. **8** shows a state in which an edge of an assist pattern is moved. Each of the edges **6***a* and **6***b* of the assist pattern **6** is moved respectively in one of directions of arrows. At this time point, the edge **6***a*, since the pattern **4** being a real pattern exists in a position facing the edge **6***a*, comes in contact with the pattern **4** when the edge **6***a* moves for a specified distance. Then, by extracting the region where the edge **6***a* has come in contact with the edge **4***a*, an edge to be corrected is detected (Step S**25**).

Furthermore, in the rule check in Step S**26**, by detecting a butting interval and a distance for which the edge **6***a* of the assist pattern **6** has been moved by the process in Step S**24**, a judgment is made as to whether or not the edge **4***a* is to be corrected. If the edge **4***a* is to be corrected, a correction value is determined according to the butting interval and the distance for which the edge **6***a* of the assist pattern **6** has been moved and then a correction is made to the edge **4***a*

(Step S**27**). After that, the produced assist pattern **6** is removed (Step S**28**) and the correction processing is terminated. If it is judged that no correction to the edge to be corrected is required, after the completion of the process in Step S**28**, the correction processing is terminated without making the correction. The processes in Steps S**29** and S**30** are the same as those in Steps S**18** and S**19** shown in FIG. **4**.

Next, a pattern data correcting method of a third embodiment of the present invention is explained.

FIG. **9** shows a flowchart indicating a flow of processes of a pattern data correcting method of the third embodiment of the present invention. The processes in Steps S**40** to S**42** in the third embodiment are the same as those shown in Steps SlO to S**12** in FIG. **4** in the pattern data correcting method of the first embodiment.

In the pattern data correcting method of the third embodiment, after an edge (called a first edge in the third embodiment) extending in a direction of a distance between patterns facing each other has been extracted in Step S**43**, a second edge being vertical to the first edge is further extracted (Step S**44**). Then, by extending the second edge (Step S**45**), an edge to be corrected is detected (Step S**46**).

FIG. **10** shows a state in which an edge to be corrected is detected by extending the second edge of the assist pattern. As shown in FIG. **10**, the second edges **6***c* and **6***d* being vertical to the first edges **6***a* and **6***b* of the assist pattern **6** are defined and the second edges **6***c* and **6***d* are extended. The second edges **6***c* and **6***d*, when extending for a specified distance, come in contact with the pattern **4** placed in parallel and near to the assist pattern **6**. At this time point, by extracting a region sandwiched between two points P**1** and P**2** having been in contact with each other, the edge **4***a* to be corrected can be detected.

Furthermore, in the rule check in Step S**47**, by checking a butting interval and distance for which the second edges **6***c* and **6***d* having been extended in Step S**45** come to contact with the pattern **4**, a judgment is made as to whether or not the edge **4***a* is to be corrected. If the edge **4***a* is to be corrected, a correction value is determined according to the butting interval and distance for which the second edges **6***c* and **6***d* having been extended come to contact with the pattern **4**, and the edge **4***a* is corrected (Step S**48**).

Here, the correction value of the edge **4***a* to be corrected may be determined according to an angle which the extended second edges **6***c* and **6***d* form with the edge **4***a* to be corrected of the pattern **4**. For example, a correction table created by using this angle as a parameter to determine the necessity of correction and/or a correction value may be employed as a reference.

Then, the produced assist pattern is removed (Step S**49**) and the correction processing is terminated. Moreover, if it is judged that no correction to the edge to be corrected is required, after the completion of the process in Step S**49**, the correction processing is terminated without making the correction. The processes in Steps S**50** and S**51** are the same as those in Steps S**18** and S**19** shown in FIG. **4**.

Next, a pattern data correcting method of a fourth embodiment of the present invention is explained. FIG. **11** shows a flowchart indicating a flow of processes of a pattern data correcting method of the fourth embodiment of the present invention. The processes in Steps S**60** to S**63** in the fourth embodiment are the same as those shown in Steps S**10** to S**13** in FIG. **4** in the pattern data correcting method of the first embodiment. In the fourth embodiment, the assist pattern to be produced in Step S**62** is referred to as a first assist pattern. In the pattern data correcting method of the fourth embodiment, a process in Step S**64** is additionally provided which produces a second assist pattern that fills space between the first assist pattern generated in the process in Step S**62** and the pattern placed in parallel and near to the first assist pattern.

FIG. **12** shows an example of a produced second assist pattern. The example is shown in which the second assist pattern **7** to fill the space between the first assist pattern **6** and the pattern **4** is produced. In the pattern data correcting method of the fourth embodiment, as shown in FIG. **12**, the edges **7***a* and **7***b* of the produced second assist pattern **7** placed in a region in which the first assist pattern **6** is not in contact with the pattern **4** are extracted (Step S**65**). By extracting the edge region in which the second assist pattern **7** is in contact with the pattern **4**, the edge **4***a* to be corrected can be detected (Step S**66**). Furthermore, in the rule check in Step S**67**, by checking a length (that is; butting interval) of each of the edges **6***a* and **6***b* and a length (that is; space width) of each of the edges **7***a* and **7***b* of the second assist pattern **7**, a judgment is made as to whether or not the edge **4***a* is corrected. Then, if the edge **4***a* is to be corrected, a correction value is determined according to a length of each of the edges **6***a* and **6***b* and a length of each of the edges **7***a* and **7***b*, and a correction is made to the edge **4***a*. After that, the produced first and second assist patterns **6** and **7** are removed (Step S**69**) and the correction processing is terminated. Moreover, if it is judged that no correction to the edge to be corrected is required, after the completion of the process in Step S**69**, the correction processing is terminated without making the correction. The processes in Steps S**70** and S**71** are the same as those in Steps S**18** and S**19** shown in FIG. **4**.

In the pattern data correcting method of the first to fourth embodiments, an assist pattern that fills a space portion having a specified size is first produced and an edge to be corrected is detected according to the produced assist pattern. However, an edge recognized as an isolated pattern may be first extracted. This is explained by using a fifth embodiment below.

FIG. **13** shows a flowchart indicating a flow of processes of a pattern data correcting method of the fifth embodiment of the present invention. First, after design data to produce an original drawing is input (Step S**80**), a judgment is made as to whether or not there is a region (isolated region) in which a space portion exists between patterns facing each other in an edge in framing portions of a pattern within a specified distance in a direction vertical to the edge (Step S**81**), and if the region exists, the region is detected as an isolated edge (Step S**82**). Moreover, if it is judged that there is no region meeting conditions, the routine proceeds to Step S**88**.

FIG. **14** shows a state in which an isolated edge is detected. Here, an example is shown in which the space portion **23** exists between the patterns **21** and **22** facing each other in a direction vertical to the edge **20***a* of the pattern **20** and this edge **20***a* is detected as an isolated edge.

Next, an assist pattern to fill the space portion **23** is produced (Step S**83**).

FIG. **15** shows a state in which an assist pattern is produced in a space portion which faces an isolated edge to be corrected. As shown in FIG. **15**, the assist pattern **24** to fill the space portion **23** facing the isolated edge **20***a* to be corrected that has been detected in Step S**82** is produced. After that, the edges **24***a* and **24***b* of the assist pattern **24** extending in a direction of a distance between the patterns **21** and **22** facing each other are extracted (Step S**84**).

Furthermore, in the rule check in Step **S85**, by checking a length (butting interval) of each of the extracted edges **24***a* and **24***b* and an interval between the assist pattern **24** and the isolated edge **20***a* to be corrected, a judgment is made as to whether or not the isolated edge **20***a* is corrected.

Here, to explain a specific judgment standard, a result from evaluation is shown on a dimensional characteristic of a region regarded as an isolated region in an edge in framing portions of a pattern.

FIG. **16** shows dimensional dependency of a pattern on a space width and butting interval. Changes in pattern dimensions are evaluated when the space width is changed for 200 nm, 320 nm, 560 nm, 1000 nm, and 2000 nm and when the butting interval is changed for 200 nm, 240 nm, 320 nm, 400 nm, 560 nm, 800 nm, 1000 nm, and 2000 nm by using the patterns for the evaluation shown in FIG. **14**. Moreover, the dimension of the patterns **20**, **21**, and **22** in the design data is 20 mm.

As is apparent from this graph, if the space width is 1000 nm or more, the region defined as the isolated edge **20***a* shows a dimensional characteristic as an ordinary isolated region irrespective of a butting interval value. That is, even if the space width is changed, the dimension is kept constant.

On the other hand, when the space width is 1000 nm or less, dimensional errors in the region defined as the isolated edge **20***a* gradually increases, which narrows the interval between the pattern **20** and patterns **21** and **22**. That is, if a pattern density in an area surrounding a dimensional measurement point becomes high, an etching speed in the entire region decreases and, as a result, a pattern dimension is made large. Moreover, if the butting interval becomes 2000 nm, even when the space width is made narrow, no increase in the dimensional errors occur.

According to the above evaluation results, in the case of patterns as shown in FIG. **14**, when a space portion **23** having the butting interval of 2000 nm or less between the patterns **21** and **22** facing each other exists within about 1000 nm in a direction vertical to the isolated edge **20***a*, it is judged that a correction is required. Then, when it is judged that a correction to the isolated edge **20***a* is required, by determining a correction value according to a length of each of the edges **24***a* and **24***b* and to an interval between the assist pattern **24** and the isolated edge **20***a*, the correction is made to the isolated edge **20***a* (Step **S86**). After that, the produced assist pattern is removed (Step **S87**) and the correction processing is terminated. Moreover, if it is judged that no correction to the isolated edge **20***a* is required, without making the correction, after the process in Step **S87**, the correction processing is terminated.

On the other hand, in the case of the edge having been judged not to be an isolated edge in the process in Step **S81**, a judgment is made as to whether the correction is made according to an ordinary proximity-effect correction rule (Line & Space) (Step **S88**) and, if the correction is made, by using, for example, the table **1** described above, a correction value is determined according to space and line dimensions and the correction is made (Step **S89**). If it is judged that no correction is required, the correction processing is terminated without making the correction.

In the pattern data correcting method of the first to fifth embodiments, either of the processing in which a correction is made to design data according to an ordinary proximity-effect correction rule (processes in Steps **S18**, **S19**, **S29**, **S30**, **S50**, **S51**, **S70**, **S71**, **S88** and **S89**) and the processing in which an edge of a pattern likely to be judged as requiring a correction but as an isolated edge (hereinafter called an apparently isolated edge) is detected and a correction is made according to a rule being independent of a rule to be applied to a correction to other edge (processes in Steps **S11** to **S17**, **S21** to **S28**, **S41** to **S49**, **S61** to **S69**, and **S81** to **S87**) is selected depending on conditions. However, the processing in which a correction is made to such an apparently isolated edge as above according to a rule being independent of a rule to be applied to a correction to other edge may be applied to data having been corrected first by using the ordinary proximity-effect correction rule.

Next, a pattern data correcting method of a sixth embodiment is explained.

FIG. **17** shows a flowchart indicating a flow of processes of a pattern data correcting method of the sixth embodiment of the present invention.

First, when design data to produce an original drawing is input (Step **S90**), an judgment is made as to whether or not a correction is made according to the ordinary proximity-effect correction rule (Line & Space)(Step **S91**) and, if the correction is made, a correction value is determined and according to space and line dimensions, and the correction is made (Step **S92**). When the correction was made and, if it is judged that no correction to the corrected data is required, the original design data is output to a storage medium **30** such as a hard disk drive or the like without making the correction (Step **S93**).

FIG. **18** shows an example of a pattern corrected according to space and line dimensions. One example is shown in FIG. **18** in which a correction is made to the patterns shown in FIG. **2** according to space and line dimensions. As shown in FIG. **18**, there is such an edge as the edge **4***a* of the pattern **4** whose width is made large by an influence of being recognized as an apparently isolated edge. In order to make a correction to such an edge as above, by inputting data stored in the storage medium **30** to detect an edge of an apparently isolated pattern described above and the processing (processes in Steps **S11** to **S17**, **S21** to **S28**, **S41** to **S49**, **S61** to **S69**, and **S81** to **S87**) is performed in which a correction is made according to a rule being independent of a rule to be applied to a correction to other edge (Step **S95**). Moreover, if an I-shaped portion or T-shaped portion in the processing (in Steps **S11**, **S21**, **S41**, and **S61**) of extracting the I-shaped or T-shaped portion to be performed in the pattern data correcting method of the first to fourth embodiments is not detected, or an isolated region in the processing (in Step **S81**) of detecting the isolated region to be performed in the fifth embodiment is not detected, the processing is terminated without making a correction.

Thus, by applying the pattern data correcting method of the first to sixth embodiment, a mask obtained by making a proper correction to data of a pattern having a complicated layout and affected by a proximity effect can be produced.

Finally, an example is described in which the mask produced by using the pattern data correcting method as explained above is applied to actual manufacturing of a semiconductor device.

FIGS. **19**, **20**, **21**, and **22** show cross-sectional views explaining processes of manufacturing a semiconductor. First, as shown in FIG. **19**, device isolation films **101** are formed in a silicon substrate **100**, by using an STI (Shallow Trench Insolation) method, in a manner in which each of the device isolation films **101** is buried in a trench with a depth of, for example, 300 nm. In FIG. **19**, an N-type transistor is formed in a device region on a left side on the drawing and a P-type transistor in a device region on a right side on the drawing.

Next, as shown in FIG. **20**, a sacrificial oxide film **102** is formed, for example, by a thermal oxidation method, on a

device region partitioned by the device isolation films **101**. Then, by photolithography, a photoresist film **103** is formed so that an N-type transistor forming region is exposed and a P-type transistor forming region is buried. Furthermore, by using the photoresist film **103** as a mask, ion implantation is performed to form P-type impurity diffused regions **104**, **105**, and **106** in the silicon substrate **100** in the N-type transistor forming region. The P-type impurity diffused region **104** is formed by the implantation of, for example, indium ion (In^+) with accelerated energy of 60 keV and in a dose of 1×10^{13} cm^{-2} Also, the P-type impurity diffused region **105** is formed by the implantation of, for example, indium ion (In^+) with accelerated energy of 180 keV and in a dose of 3×10^{13} cm^{-2}. The P-type impurity diffused region **106** is formed by the implantation of, for example, boron ion (B^+) with accelerated energy of 150 keV and in a dose of 3×10^{13} cm^{-2}.

Next, as shown in FIG. **21**, by photolithography, a photoresist film **107** is formed so that the P-type transistor forming region is exposed and the N-type transistor forming region is buried. Then, by using the photoresist film **107** as a mask, ion implantation is carried out to form N-type impurity diffused regions **108**, **109**, and **110** in the silicon substrate **100** in the P-type transistor forming region.

The N-type impurity diffused region **108** is formed by the implantation of, for example, arsenic ion (As^+) with accelerated energy of 100 keV and in a dose of 5×10^{12} cm^{-2}. Also, the N-type impurity diffused region **109** is formed by the implantation of, for example, arsenic ion (As^+) with accelerated energy of 150 keV and in a dose of 5×10^{13} cm^{-2}. The N-type impurity diffused region **110** is formed by the implantation of, for example, phosphorus ion (P^+) with accelerated energy of 300 keV and in a dose of 3×10^{13} cm^{-2}.

Next, by carrying out wet-etching using, for example, a hydrofluoric water solution, the sacrificial oxide film **102** is removed. Then, for example, by the thermal oxidation method, a silicon oxide film with a film thickness of, for example, 11 nm is made to grow on a device region that is exposed by the removal of the sacrificial oxide film **102** and, as shown in FIG. **22**, a gate insulating film **111** made of a silicon oxide film is formed. Then, a polycrystalline silicon film (not shown) with a film thickness of, for example, 100 nm is deposited on the gate insulating film **111**, for example, by a CVD (Chemical Vapor Deposition) method. Next, an organic anti-reflection film **112** is applied on the polycrystalline silicon film so that its film thickness is about 80 nm and, furthermore, an ArF (Argon Fluoride) posi-type resist serving as a photosensitive material is applied thereon so that its thickness is about 250 nm to 300 nm.

By a stepper using an ArF exima laser as a light source, exposures of a pattern for a mask produced by the pattern data correcting method in the first to sixth embodiments are performed on the wafer substrate in the state described above. The exposure is performed under conditions of a numerical aperture (NA) being 0.7, ½ zonal illumination (σ value:0.425/0.85), and an amount of exposure being 210 J/cm^2.

Next, by thermal treatment as a post exposure baking (PEB) process and developing processing, a resist pattern **113** is formed. Then, by using the resist pattern **113** as a mask, the anti-reflection film **112**, the polycrystalline silicon film (not shown), and the gate insulating film **111** are etched to form gate electrodes **114** and **115** made up of a polycrystalline silicon film. Here, the gate electrode **114** serves as a gate electrode of an N-type transistor and the gate electrode **115** serves as a gate electrode of a P-type transistor.

Thus, a study on uniformity in pattern dimensions of the gate electrodes **114** and **115** formed by using the pattern data correcting method employed in the first to sixth embodiments shows that dimensional uniformity obtained by using the mask produced by the pattern data correcting method of the present invention is improved by about 4 nm in length when compared with the case of using the conventional mask.

Moreover, in all the above first to sixth embodiments, the pattern data correcting method is applied when a correction is made to a pattern formed on a mask. However, the pattern data correcting method of the present invention can be also applied when the correction is to be made to data of a pattern which is affected by a proximity effect and is formed on a wafer.

According to the present invention, since a space portion being formed on a photomask or a wafer and having a specified size occurring between patterns facing each other in a first direction is detected according to design data, pattern data corresponding to an assist pattern that fills the space portion is produced, an edge to be corrected placed in a position being opposite to an edge of an assist pattern extending in a second direction between patterns facing each other, out of framing portions of the pattern positioned in parallel and near to the assist pattern, is detected, and a correction being independent of a correction to be made to other edge in the framing portion of the pattern is made to an edge to be corrected, it is possible to make a proper correction to even an edge which is ordinarily recognized as an isolated pattern and to which a proper correction is not made.

Also, since a region where a space portion occurring between second patterns facing each other, out of edges in framing portions of the second pattern, exists is extracted as an isolated edge, pattern data corresponding to an assist pattern that fills the space portion is produced, an edge of an assist pattern extending in a second direction of a distance between the first and second patterns facing each other is extracted, and a correction is made to the isolated edge according to a length of the extracted assist pattern and to an interval between the assist pattern and the above isolated edge, it is possible to make a proper correction to even an edge which is ordinarily recognized as an isolated pattern and to which a proper correction is not made.

Furthermore, by applying a photomask formed by using the above methods to a process of manufacturing a semiconductor device, it is made possible to form a desired microfabricated pattern.

The foregoing is considered as illustrative only of the principles of the present invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and applications shown and described, and accordingly, all suitable modifications and equivalents may be regarded as falling within the scope of the invention in the appended claims and their equivalents.

What is claimed is:

1. A pattern data correcting method for making a correction to pattern data affected by a proximity effect when a pattern is formed on a photomask or wafer according to design data for a semiconductor device, comprising the steps of:

- detecting, according to said design data, a space portion on said photomask or wafer and having a specified size occurring between first and second patterns facing each other;
- producing pattern data corresponding to an assist pattern that fills said space portion;
- detecting, on a third pattern near to said assist pattern, an edge to be corrected in a position out of framing portions of said third pattern and opposite to and parallel with an edge of said assist pattern, said edge of

said assist pattern extending in a direction between said first and second patterns facing each other;

making a correction to the detected edge, said correction being independent of a correction made to an other edge of said third pattern; and

removing said assist pattern.

2. The pattern data correcting method according to claim 1, wherein said pattern data corresponding to said assist pattern is defined by a layer or a variable different from that for said design data.

3. The pattern data correcting method according to claim 1, wherein said space portion is a region between said first and second patterns, which face each other in a T-shaped or an I-shaped manner.

4. The pattern data correcting method according to claim 1, wherein said edge to be corrected is detected by extracting a region in a position opposite to said edge of said assist pattern and having a length the same as that of said edge of said assist pattern.

5. The pattern data correcting method according to claim 1, wherein said edge to be corrected is detected by moving said edge of said assist pattern so as to come in contact with said edge to be corrected and extracting a region of said edge of said assist pattern which is in contact with said edge to be corrected to detect said edge to be corrected.

6. The pattern data correcting method according to claim 1, wherein said edge to be corrected is detected by extending two lines out from said assist pattern, said two lines being perpendicular to said edge of said assist pattern extending in direction between said first and second patterns and by extracting a region formed between two points where said two lines contact with said third pattern.

7. The pattern data correcting method according to claim 6, wherein a correction value for said edge to be corrected is determined according to an angle formed between one of said two lines with said edge to be corrected.

8. The pattern data correcting method according to claim 1, further comprising a step of forming a second assist pattern that fills a space between said assist pattern and said third pattern and located in parallel with and near to said assist pattern, wherein said edge to be corrected is detected by extracting a region where said second assist pattern is in contact with said third pattern.

9. The pattern data correcting method according to claim 1, wherein processing in each step is performed on design data having been corrected according to predetermined rules.

10. The pattern data correcting method according to claim 9, wherein said predetermined rules are correcting rules according to which a correction value is determined according to a line dimension of said third pattern and to a space dimension between said patterns.

11. A pattern data correcting method for making a correction to pattern data affected by a proximity effect when a pattern is formed on a photomask or wafer according to design data for a semiconductor device, comprising the steps of:

detecting an isolated edge region out of framing portions of a first pattern, in which a space width occurring between a second pattern and a third pattern facing each other and said first pattern exists within a specified distance;

producing pattern data corresponding to an assist pattern that fills a space portion between said second and third patterns;

extracting an edge of said assist pattern extending between said second and third patterns facing each other in a second direction;

making a correction to data of said isolated edge according to a length of said edge of said assist pattern and an interval between said assist pattern and said isolated edge; and

removing said assist pattern.

12. The pattern data correcting method according to claim 11, wherein said pattern data corresponding to said assist pattern is defined by a layer or a variable which is different from that for said design data.

13. The pattern data correcting method according to claim 11, wherein processing in each step is performed on design data having been corrected according to predetermined rules.

14. The pattern data correcting method according to claim 13, wherein said predetermined rules are correcting rules according to which a correction value is determined according to a line dimension of said first pattern and to a space dimension between said second and third patterns.

15. A method for manufacturing a semiconductor device comprising:

forming a photomask by

detecting, according to said design data, a space portion on said photomask or wafer and having a specified size occurring between first and second patterns facing each other,

producing pattern data corresponding to an assist pattern that fills said space portion,

detecting, on a third pattern near to said assist pattern, an edge to be corrected in a position out of framing portions of said third pattern and opposite to and parallel with an edge of said assist pattern, said edge of said assist pattern extending in a direction between said first and second patterns facing each other,

making a correction to the detected edge to be corrected, said correction being independent of a correction made to an other edgeof said third pattern, and

removing said assist pattern; and

performing an exposure by using said photomask.

16. A method for manufacturing a semiconductor device comprising:

forming a photomask by

detecting an isolated edge region out of framing portions of a first pattern, in which a space width occurring between a second pattern and a third pattern facing each other and said first pattern exists within a specified distance,

producing pattern data corresponding to an assist pattern that fills a space portion between said second and third patterns,

extracting an edge of said assist pattern extending between said second and third patterns facing each other in a second direction,

making a correction to data of said isolated edge according to a length of said edge of said assist pattern and an interval between said assist pattern and said isolated edge, and

removing said assist pattern; and

performing an exposure by using said photomask.

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